

ISSN: 3124-4467



PROCEEDINGS OF INTERNATIONAL CONFERENCE ON RESEARCH IN EDUCATION (ICRE) 2025

Faculty of Teacher Training and Education
Universitas Sanata Dharma
Indonesia



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Universitas Sanata Dharma
27-28 November 2025
Yogyakarta, Indonesia

PROCEEDINGS OF INTERNATIONAL CONFERENCE ON RESEARCH IN EDUCATION (ICRE) 2025

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ISSN: 3124-4467

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DEVELOPING *MATHCITYMAP* ACTIVITIES TO SUPPORT THE HAPPINESS OF JUNIOR HIGH STUDENTS

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Received: 10 September 2025; Accepted: 23 October 2025

Abstract

Math is often seen as a difficult subject and causes anxiety. This is due to students' own perceptions, which make them unhappy in learning mathematics. In fact, student happiness in learning mathematics is an important aspect that can affect student learning outcomes. Therefore, this study aims to develop contextual mathematics learning activities with MathCityMap to support student happiness. This research uses the ADDIE (Analyze, Design, Development, Implementation, Evaluation) model in its development. The data collection techniques used were semi-structured interviews, implementation observation, and questionnaire distribution. The questionnaire responses before the application of the high level of happiness indicated that 16 students reported a high level of happiness. While the results of the questionnaire response after implementation, the level of high happiness amounted to 13 students. There was an insignificant decrease in student happiness. This decrease was caused by technical constraints, high temperatures, and problem places that could not be used.

Keywords: development research, happiness, MathCityMap, neuroscience

Introduction

Most students view math as a difficult subject that can even cause anxiety. This occurs due to students' own perceptions that math is difficult and boring (Aprilia & Fitriana, 2022). Students' perceptions are reinforced by abstract and complex mathematical formulas and concepts that often make it difficult for students to understand the material. The use of learning methods that mostly use conventional methods, so students are less actively involved in learning, also worsens students' perceptions. As a result, students experience a decrease in their interest and happiness in learning mathematics (Aulia et al., 2024). Students' happiness in learning mathematics is an important aspect that affects their learning outcomes. Research by Jannah and her colleagues shows that happiness can improve the quality of learning while contributing to the achievement of better learning outcomes (Jannah & Hadiyanto, 2024). To better understand why happiness relates to these learning outcomes, we next consider a neuroscience perspective.

Neuroscience is a field of science that explores the nervous system, especially the brain mechanisms that control various aspects of human life (Rudhito, 2024). From a neuroscience perspective, happiness is closely related to the function of the nervous system and the activity of chemical compounds in the brain, including



neurotransmitters and the limbic system. Neurotransmitters are chemicals that help the communication process between neurons in the brain (Anggraini, 2023). Neurotransmitters such as dopamine, serotonin, oxytocin, and endorphins have an important role in triggering happiness (Hanim, 2021). Dopamine is a neurotransmitter that functions in the brain's reward system (Duitasari & Safitri, 2022). This chemical is released when a person experiences pleasant things (Pangestuti & Janah, 2023). Serotonin has a role in regulating mood as well as a sense of satisfaction. Serotonin imbalance causes a condition often referred to as depression (Deakin, 2020). Oxytocin, known as the love hormone, serves to strengthen social bonds and increase trust in relationships. Oxytocin can increase when a person has interactions such as physical contact and warmth. On the other hand, endorphins act as painkillers and can increase feelings of euphoria after intense physical activity or exercise (Khairunnisa et al., 2025). The limbic system, consisting of the hypothalamus, amygdala, and hippocampus, is the part of the brain that regulates emotions, including happiness (Wartani et al., 2023).

In our context, three related problems persist: (1) many students perceive mathematics as abstract and difficult; (2) classroom practice is still largely teacher-centered with limited links to everyday situations; and (3) these conditions dampen students' enjoyment and intrinsic motivation to learn. A contextual learning approach offers a solution by emphasizing the active involvement of students in understanding the material by linking it to real situations, so that students are motivated to apply the knowledge gained in everyday life (Muhartini et al., 2023). By being student-centered, this approach allows them to actively build an understanding of abstract and complex mathematical concepts. With students actively involved in learning, mathematical concepts become more meaningful and relevant to students, as well as creating a fun learning experience (Anggin et al., 2023). This positive experience can increase the release of dopamine, one of the neurotransmitters associated with happiness (Pangestuti & Janah, 2023). This increase in dopamine can also increase students' intrinsic motivation (Freed, 2022).

MathCityMap is a GPS-based application that supports math learning outside the classroom by connecting math concepts to real situations through environmental exploration using maps and exploration paths (Muliasari et al., 2023). Based on the definition of *MathCityMap*, this application provides the possibility for students to learn math contextually outdoors by linking it to situations in everyday life. *MathCityMap* can be a math learning application that encourages students to be active in learning (Taufik & Suryani, 2024) and makes math learning fun (Lubis et al., 2021). Based on the explanation of the background above, this research aims to develop *MathCityMap* activities that can support students' happiness in learning math.

Several previous studies are relevant to this research, namely research conducted by Lubis et al. (2021), which aims to facilitate students' mathematical understanding by using ethnomathematics concepts using the *MathCityMap* application. Research by Alamanda and Zainil (2024) aimed to develop *MathCityMap* in flat building materials. Research conducted by Anas and Umar (2021) aimed to determine the factors that can affect student happiness. Lastly, research conducted by Hasibuan (2020) aimed to determine the factors of student learning happiness during COVID-19. The novelty of this research with previous

research is the development of *MathCityMap* with neuroscientific indicators of happiness.

A preliminary needs analysis was carried out involving classroom observations, curriculum review (Grades VII–VIII), and short interviews with the mathematics teacher and 6 student representatives. The results indicated that (1) many students still perceived mathematics as abstract and difficult; (2) instruction was predominantly teacher-centered with limited links to everyday contexts; (3) students' enjoyment and intrinsic motivation fluctuated, especially in outdoor activities due to time of day and heat; (4) schools had mixed device/network readiness for mobile learning; and (5) there was no classroom-ready instrument to monitor happiness aligned with neuroscience-informed indicators. These needs point to the development of a set of *MathCityMap* activities that are contextual, student-centered, and technically feasible for the school setting, accompanied by a validated happiness questionnaire. The novelty of this study lies in developing MCM activities together with neuroscience-based happiness indicators for middle-school learners.

Method

The type of research used was R&D (Research and Development), with development steps that adopted the ADDIE model (Analyze, Design, Development, Implementation, Evaluation). R&D is research with the aim of producing a specific product. (Okpatrioka, 2023). The research subjects were students of class VIII F SMP Negeri 1 Piyungan, Yogyakarta. The research was conducted in the period of September 2024 - March 2025. The data collection was conducted by several methods, namely semi-structured interviews, observation of implementation, and distribution of questionnaires.

There are two types of data obtained from the data collection, namely qualitative data and quantitative data. The qualitative data were analyzed and used to make improvements to the *MathCityMap* activity. Meanwhile, the qualitative data (interviews, observations, and open-ended responses) were analyzed using thematic content analysis, which involved familiarization, open coding, grouping codes into categories aligned with the happiness indicators, theme generation, and peer debriefing to reach consensus. The findings were summarized in a matrix with representative quotes and used to refine the *MathCityMap* activities. Meanwhile, the quantitative data were analyzed using the average percentage formula of the scores obtained, then grouped into existing criteria. The quantitative data obtained are the results of the *MathCityMap* activity validation assessment and the results of student responses to the happiness questionnaire. The validation results of the *MathCityMap* activities were then calculated, and the percentages of the score obtained were categorized into the validity category criteria in Table 1. The results of students' responses to the happiness questionnaire, the total score obtained, were categorized into the criteria for the happiness interval category in Table 2, whose calculation was adopted from the object categorization (Azwar, 1999).

Table 1. Criteria Category of Validity of *MathCityMap* Activity

Score (Percent)	Category of Validity
85% - 100%	Very Valid
70% - 84%	Valid
55%-69%	Valid Enough
< 55%	Less Valid

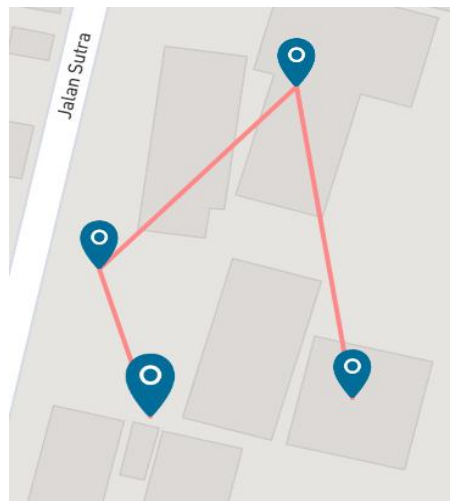
Table 2. Happiness Level Interval Criteria

Calculations	Category
25 - 49	Low
50 - 74	Medium
75 - 100	High

Findings and Discussion

Result

The *MathCityMap* activity was developed by applying material from grades 7 and 8, namely volume of space, number patterns, and surface area. The material was taken by analyzing the material from the Ministry of Education website and based on interviews with math teachers. Researchers developed 4 stopping points in the environment around the school, namely the fish pond, gazebo, back room of the hall, and indoor field. The picture below is a picture of the path that students take in the *MathCityMap* activity.

Figure 1. *MathCityMap* Activity Trail

The first activity has a stopping point at the fish pond at the school. The problem that students must solve is to find out the volume of water in the fish pond when it is filled to the brim. As seen in the picture, the fish pond is in the shape of a block, but with one side having a different height. In addition, in the middle of the pond, there is a fountain that looks like a tube. This became a challenge for students in solving the contextual problem. To get the right answer, students simply calculate the volume of the block by taking the smallest height and reducing the volume with the volume of the fountain.



Aktivitas 1: Kolam Ikan

Di dalam area sekolah, terdapat sebuah kolam ikan yang posisinya berada tepat di sebelah lapangan bulu tangkis. Penjaga kebun sekolah ingin mengisi kolam ikan ini dengan air hingga penuh. Berdasarkan ukuran dan kapasitas kolam, berapa liter air yang diperlukan penjaga kebun untuk mengisi kolam ikan tersebut secara penuh?

volume

Bangun ruang

Figure 2. First Activity

The second activity is in the gazebo, which is located not too far from the fish pond. The gazebo has a rectangular pyramid-shaped roof. At this point, students are asked to calculate the number of roof tiles needed for the gazebo if the length of the roof side is increased by 1 meter. It is a challenge for students because students will be asked to calculate the number of roof tiles for the gazebo using the arithmetic formula. The gazebo tile is triangular with a tile pattern; each row has a difference of two tiles.



Aktivitas 2 : Gazebo

Di pinggir lapangan basket terdapat dua buah gazebo yang disediakan bagi siswa dan guru untuk beristirahat atau berteduh. Masing-masing gazebo memiliki atap dengan bentuk tertentu, dan kini direncanakan untuk memperluas atapnya dengan cara menambah panjang setiap sisi sebesar 1 meter. Berdasarkan rencana perluasan ini, berapa banyak genteng yang diperlukan oleh pemborong untuk menutupi seluruh permukaan atap dari satu gazebo?

Figure 3. Second Activity

In the third activity, students were asked to determine the paint cans needed to paint the room behind the hall. In this problem, students need to calculate the surface area of the inside wall of the room. It should be noted that in the walls of the room, there are windows, doors, and also unpainted switches, so students need to reduce the surface area of the walls that have windows, doors, and switches. The problem also contains information about how one can of paint can cover 120.000 cm^2 .



Aktivitas 3 : Ruangan

Di bagian belakang aula SMP Negeri 1 Piyungan, terdapat beberapa ruangan yang baru saja selesai diperbaharui dan dicat ulang agar terlihat lebih segar. Untuk pengecatan ini, setiap ruangan dicat menggunakan cat berwarna hijau. Jika diketahui bahwa satu kaleng cat dapat menutupi area seluas 120.000 cm^2 , berapa kaleng cat yang diperlukan untuk mengecat seluruh dinding dari satu ruangan tersebut?

luas permukaan

Figure 4. Third Activity

The last activity takes place on an indoor court. This activity asks students to calculate the number of paving blocks needed to cover the base of the indoor field. It is known that the paving blocks of the field are hexagonal. Students will certainly find it difficult if they choose to solve the problem by counting the paving blocks one by one. Therefore, the challenge for students in solving this last problem is to calculate the area of the hexagon (paving blocks).

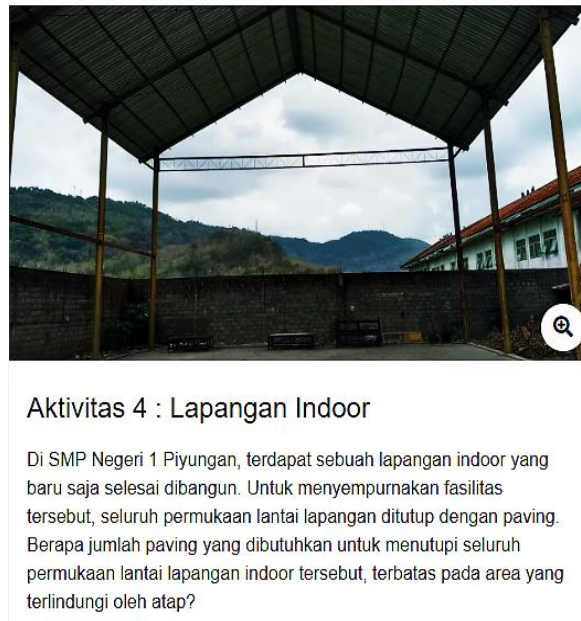


Figure 5. Fourth Activity

In addition to the *MathCityMap* activities above, the researchers also developed research instruments, one of which was a questionnaire for students' happiness in learning mathematics both before and after implementation. The pre-implementation questionnaire consisted of 25 questions, while the post-implementation questionnaire consisted of 22 questions. The researcher used a Likert scale in both questionnaires with four options to avoid doubts in the response results. The *MathCityMap* activities and questionnaires were then validated to determine their quality. This validation was done by two validators who assessed several aspects. Table 3 contains the validation results of the *MathCityMap* activity, while Table 4 contains the validation results of pre- and post-implementation questionnaires.

Table 3. Percentage of Validation Results

Indicator	Percentage		Average	Validity Category
	Validator 1	Validator 2		
Conformance to Curriculum and Learning	87,5%	87,5%	87,5%	Very Valid
Support to Student Happiness	91,6%	83,3%	87,45%	Very Valid
Student Engagement	100%	75%	87,5%	Very Valid
Ease of Use	81,25%	87,5%	84,37%	Valid
Aesthetics and Display	100%	87,5%	93,75%	Very Valid

Table 4. Percentage of Questionnaire Validation Results

Validator	Questionnaire Before	Questionnaire After
1	94%	92%
2	76,5%	81,25%
Total	85,25% (very valid)	86,62% (very valid)

Before applying the *MathCityMap* activities above, students first took a questionnaire about happiness in learning math. After filling out the questionnaire, the students were divided into six groups, and each group had a gadget to be able to access the *MathCityMap* activity above. The first step that students took to access the activity above was to download the *MathCityMap* application. Next, the students selected the "Add Trail" menu, entered the trail code 4923618 in the space provided, and downloaded the trail to be able to access the activity and solve the problem. After the students finished working on the *MathCityMap* activity above, they were given another questionnaire about happiness in learning math after the application. Below are the graphs of student response results from the two questionnaires given.

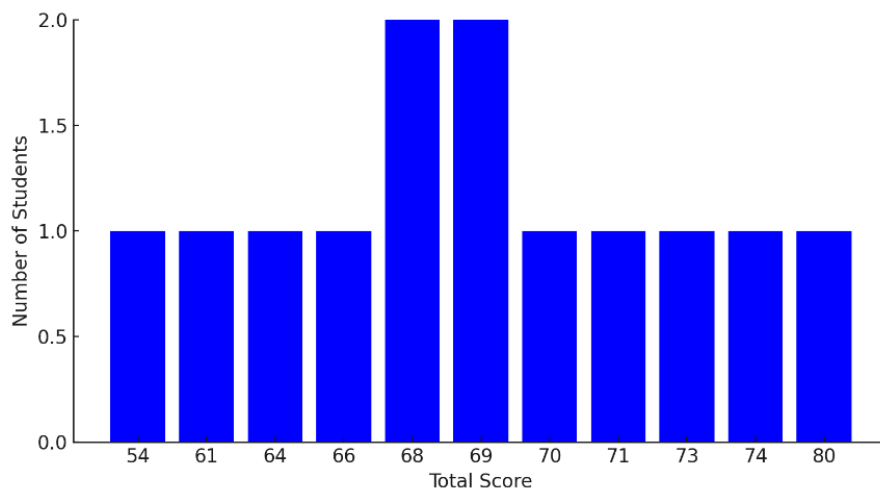


Figure 6. Student Response Results Questionnaire before Implementation

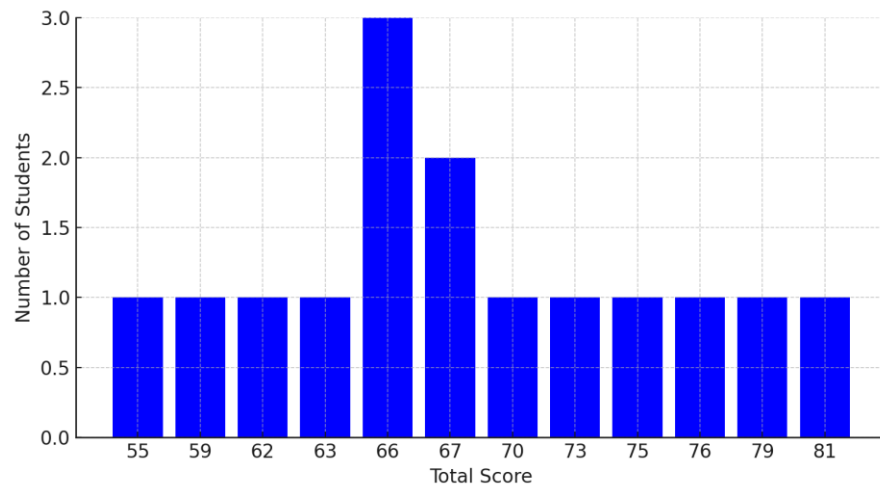


Figure 7. Student Response Results Questionnaire after Implementation

On the criteria for the interval category of happiness levels described in the method section, the students' responses to the questionnaire before implementation in the medium and high categories were the same number, with 16 students. Meanwhile, the students' responses to the questionnaire after implementation showed an increase in the moderate category, namely a total of 19 students, and in

the high category, there was a decrease to 13 students. Overall, the questionnaire before implementation received a total score of 2.332, and the questionnaire after implementation received a total score of 2.300.

Discussion

This study followed the ADDIE model—analyze, design, development, implementation, and evaluation. In the analysis stage, the researchers compiled neuroscience-informed indicators of happiness (engagement, intrinsic motivation, positive affect, social interaction, and learning satisfaction) as the basis for designing the MathCityMap (MCM) activities. The product and the happiness questionnaire obtained high validity, and the implementation produced small shifts in students' happiness categories.

The current findings are consistent with prior research, showing that contextual learning increases students' motivation to apply mathematical ideas to everyday life (Muhartini et al., 2023) and that MCM can support understanding of geometric topics through authentic outdoor tasks (Alamanda & Zainil, 2024). With student-centered tasks, abstract concepts become more meaningful and enjoyable, which echoes evidence that enjoyment and relevance are key contributors to students' learning happiness (Anas & Umar, 2021; Hasibuan, 2020). The present study extends this line of work by integrating a neuroscience-based set of indicators into both the design of activities and the evaluation instrument.

Mechanisms from a neuroscience lens. The positive experience afforded by contextual, collaborative tasks plausibly triggers neurotransmitter activity associated with happiness. Neurotransmitters facilitate communication between neurons (Anggraini, 2023); among them, dopamine, serotonin, oxytocin, and endorphins are implicated in reward, mood regulation, social bonding, and pleasurable states (Hanim, 2021). Learning experiences that are goal-directed, socially interactive, and physically engaging can increase dopamine release, thereby sustaining attention and motivation (Pangestuti & Janah, 2023). Positioning the design within these mechanisms clarifies why well-structured MCM tasks can support students' happiness in mathematics (see also Rudhito, 2024).

Interpretation of the small score changes. The modest aggregate change in happiness after implementation is understandable given contextual constraints noted during fieldwork—mixed device/network readiness and mid-day heat—which reduced time-on-task and comfort for some groups. These conditions likely attenuated the very mechanisms (sustained engagement, positive affect, and smooth social interaction) that the design seeks to activate. Thus, rather than indicating a weak design, the results point to implementation levers.

Implications. To realize the full potential of contextual, neuroscience-informed activities, future implementations should (i) schedule sessions in the morning or in shaded indoor–outdoor transitions, (ii) conduct pre-checks for accounts, device availability, and connectivity, and (iii) provide a brief orientation on MCM use. These adjustments target the same indicators we measure—engagement, positive affect, and social interaction—and are expected to amplify their effects.

Based on the research results above, it is known that there is an insignificant decrease in the level of student happiness. This can be seen in the happiness interval category of three students who decreased from a high level to a moderate level. This decrease was caused by several obstacles in the application of *MathCityMap*

activities. The first obstacle was technical constraints in accessing the activities. There were groups of students who could not access the *MathCityMap* activity even though the access code entered was correct. This technical obstacle was quite time-consuming in implementing the *MathCityMap* activities, so students could only do three out of four activities.

The second obstacle was that one of the places in the *MathCityMap* activity cannot be used because it is being used by the school. This caused students to measure another room next to it, which had a slight difference in size. In addition, the numbers from the measurement results are large enough to confuse students. The implementation time, which was in the afternoon, also caused an insignificant decrease in students' happiness level. During the day, the air temperature increased, which caused students to feel uncomfortable and stressed (Putri, 2022). It is known that stress can cause an imbalance in the neurotransmitters serotonin and dopamine (Dalvi-Garcia et al., 2021).

Conclusion

Based on the results and discussion of the research above, it can be concluded that the *MathCityMap* activities obtained an overall percentage of 87.5% and were valid and feasible to be applied. The students' responses in the questionnaire before implementation showed that the level of moderate and high happiness obtained the same number of 16 students. Meanwhile, the results of student responses in the questionnaire after implementation showed that the level of moderate happiness was 19 students, and a high level of 13 students. There was an insignificant decrease in the level of student happiness. The decrease was caused by several obstacles in the implementation, namely technical obstacles that were quite time-consuming, the unusable room, and the implementation time during the day, when the high air temperature caused the students stress and affected the results of student responses. Therefore, researchers provide several suggestions that the implementation time should be done in the morning, when the air temperature is not too high, so that the response results can be even better. If carried out outdoors, the application of *MathCityMap* activities should consider the weather. Further, there should be a tutorial on how to use the application before the implementation to minimize technical problems.

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EXPLORING STUDENTS' UNDERSTANDING OF LINEAR AND QUADRATIC RELATIONSHIPS IN A PROJECTILE MOTION CONTEXT

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Received: 5 November 2025; Accepted: 27 November 2025

Abstract

Previous research has shown that students often struggle to develop an understanding of linear and quadratic relationships. Covariational reasoning has been identified as a way to support this development. This study aims to investigate how covariational reasoning supports students in developing understandings of linear and quadratic relationships within a projectile motion context. A teaching experiment was conducted with two middle school students who engaged in a digital task exploring the relationship between height and time. The analysis characterizes how the students' covariational reasoning evolved as they interpreted the changing quantities in the task. The findings suggest that prompts encouraging students to compare linear and quadratic relationships can foster more sophisticated forms of covariational reasoning. The discussion highlights how specific features of the task design, including the affordances of technology, the emphasis on conceiving graphs as representations of covarying quantities, and the use of non-canonical graphing tasks, can support covariational reasoning.

Keywords: covariational reasoning, linear relationship, projectile motion, quadratic relationship

Introduction

Linear and quadratic relationships are essential for interpreting real-world phenomena (Abrams, 2023; Stewart et al., 2016), yet many studies have shown that students continue to struggle in understanding these relationships (Van Dooren et al., 2008). For instance, students often struggle to connect the algebraic forms of linear and quadratic relationships with their graphical representations and the real-world situations they model (Leinhardt et al., 1990; Wilkie, 2019; Wilkie & Ayalon, 2018). These challenges suggest the need for instructional approaches that help students develop deeper, more connected understandings of how quantities change together, such as through covariational reasoning.



Covariational reasoning, or reasoning about how two quantities change in tandem, is fundamental for students' understanding of mathematical relationships (Thompson & Carlson, 2017). Using this reasoning allows them to interpret functions dynamically, bridging algebraic expressions, graphs, and contextual situations. Prior studies have shown that promoting covariational reasoning can help students develop an understanding of the rate of change (Tallman et al., 2024; Yu, 2024), concepts that underlie both linear and quadratic relationships. Consequently, fostering covariational reasoning may be a productive way to address students' challenges in understanding linear and quadratic relationships.

Therefore, this study employed a teaching experiment to characterize how students' covariational reasoning supports their development of understanding of linear and quadratic relationships. We drew on the covariational reasoning framework (Thompson & Carlson, 2017) to analyze how students reasoned about varying quantities as they engaged with tasks involving these relationships. This analysis allowed us to trace how their reasoning evolved and supported conceptual development. The study offers empirical insights into the role of covariational reasoning in fostering students' understanding of fundamental functional relationships in mathematics. The following sections review relevant literature and theoretical perspectives before describing the methods and presenting the findings.

Literature Review

Previous research has highlighted the potential of covariational reasoning to support students in developing meaningful understandings of mathematical relationships. One productive approach for fostering such reasoning is through the use of real-world phenomena. For example, Sandoval Jiménez and Sierra (2025) designed a modeling task based on a Newtonian problem in which students were asked to calculate temperatures beyond the range measurable by a thermometer. They found that engaging in this modeling task promoted students' covariational reasoning. Similarly, Yu (2025) and Altindis (2025) incorporated motion-based contexts into their tasks to foster covariational reasoning. Such contexts draw on students' intuitive understandings of physical phenomena, allowing them to focus on coordinating quantities that are familiar to them (Yu, 2025). Such real-world contexts can also generate an intellectual need for students to make sense of mathematical ideas through covariational reasoning (Harel, 2013; Paoletti, Moore, et al., 2024).

However, students often encounter difficulties when modeling real-world phenomena, particularly those involving motion contexts. A common challenge is that students tend to interpret graphs representing quantities in such phenomena using a spatial coordinate system, even when this interpretation is inappropriate (Paoletti, Hardison, et al., 2022). In other words, students often treat the graph as a literal depiction of the phenomenon, interpreting it as a picture or map of the physical situation rather than as a representation of how quantities covary. One promising approach to address this issue is to encourage students to conceive of a graph both in terms of what is produced (a trace) and how it is produced (via covarying quantities) (Moore & Thompson, 2015). Another is to employ non-canonical graphing tasks, for example, those that represent time on the vertical axis and height on the horizontal axis. These unconventional representations can challenge students' assumptions and engage them in novel reasoning processes,

including quantitative and covariational reasoning, even when they are familiar with conventional graph forms (Moore et al., 2014). By disrupting familiar visual associations, such tasks can promote more flexible and conceptual understandings of functional relationships.

Previous studies have also leveraged the affordances of technology to promote students' covariational reasoning in modeling dynamic situations. For example, Johnson (2020) used technology to display a video animation of a moving car alongside a sketching panel that allowed students to construct graphs representing the quantities involved in the situation. This design provided opportunities for students to engage in covariational reasoning. Pittalis et al. (2025) employed similar technological affordances to facilitate students in graphically representing motion scenarios involving covarying quantities. However, their task design further utilized the affordance of directly linking the graph to the animation, allowing students to observe how changes in one representation corresponded to changes in the other. Such uses of technology illustrate its potential not only to visualize dynamic relationships but also to create integrated environments where students can coordinate multiple representations (Ainsworth, 1999), thereby deepening their understanding of how quantities change together.

Taken together, these studies suggest that engaging students with real-world phenomena, encouraging them to conceive of graphs as representations of covarying quantities, and introducing non-canonical graphing tasks can provide meaningful contexts for promoting covariational reasoning. Moreover, the affordances of technology can further enhance these learning experiences by enabling students to dynamically link representations and observe quantitative changes in real time.

Theoretical framework

Covariational reasoning refers to the ability to mentally envision two or more quantities changing at the same time, maintaining a continuous awareness of their values and how those values vary together (Saldanha & Thompson, 1998). Thompson and Carlson (2017) describe covariational reasoning as progressing through several developmental levels, summarized in Table 1, ranging from a lack of coordination between varying quantities to a sophisticated understanding of two variables varying smoothly and continuously.

Table 1. Covariational Reasoning Framework (Thompson & Carlson, 2017)

Level	Description
No coordination	The person has no image of variables varying together. The person focuses on one or another variable's variation with no coordination of values.
Pre-coordination of values	The person envisions two variables' values varying, but asynchronously—one variable changes, then the second variable changes, then the first, and so on. The person does not anticipate creating pairs of values as multiplicative objects.

Gross coordination of values	The person forms a gross image of quantities' values varying together, such as "this quantity increases while that quantity decreases." The person does not envision that individual values of quantities go together. Instead, the person envisions a loose, non-multiplicative link between the overall changes in two quantities' values.
Coordination of values	The person coordinates the values of one variable (x) with values of another variable (y) with the anticipation of creating a discrete collection of pairs (x, y).
Chunky continuous covariation	The person envisions changes in one variable's value as happening simultaneously with changes in another variable's value, and they envision both variables varying with chunky continuous variation.
Smooth continuous covariation	The person envisions increases or decreases (hereafter, changes) in one quantity's or variable's value (hereafter, variable) as happening simultaneously with changes in another variable's value, and the person envisions both variables varying smoothly and continuously.

The framework of covariational reasoning presented in Table 1 does not explicitly include the rate of change. According to Thompson and Carlson (2017), conceptualizing rate of change requires covariational reasoning but also involves more conceptualizations, such as ratio and quotient. Accordingly, attending to how students quantify a rate of change can offer valuable insights into their covariational reasoning and inform how instruction might better support students in reasoning at more advanced levels (Yu, 2024).

Current study

The present study aims to explore how covariational reasoning supports students in developing an understanding of linear and quadratic relationships in a projectile motion context. Therefore, this study addresses the following research question: How does covariational reasoning support middle school students in developing meanings for linear and quadratic relationships in a projectile motion context?

Methods

This study employed a teaching experiment (Steffe & Thompson, 2000) to characterize two students' activity as they engaged with the *Height-Time Relationship Task*. The task was part of a larger project aimed at promoting emergent graphical shape thinking, in which students interpret and construct graphs representing covarying quantities (Kristanto et al., 2025; Kristanto & Lavicza, 2025). The teaching experiment was conducted by the first author, who served as the teacher-researcher (TR) and facilitated the students' engagement with the task. In this study, we examined how covariational reasoning supported students in developing meanings for linear and quadratic relationships. The following sections describe the participants, the task, and the analytical approach.

Participants

The participants were two female ninth-grade students from a public middle school in Yogyakarta, Indonesia. TR was not the students' regular classroom teacher, which helped create an exploratory learning environment distinct from their usual classroom setting. The students, referred to by the pseudonyms Fania and Bianca, were selected based on two criteria. First, they represented diverse academic abilities. Second, both demonstrated strong verbal communication skills, which were important for generating rich verbal data during the teaching experiment. The selection of participants was assisted by the students' regular mathematics teacher, who identified candidates meeting these criteria. The participating school was chosen for its familiarity with using technology, such as laptops or tablets, in classroom instruction.

The Height-Time Relationship Task

The Height-Time Relationship Task was part of a larger digital task sequence titled "How Accurate Is Your Aim?"¹ which was designed to provide a game-based learning environment that supports students' engagement in emergent graphical shape thinking as they interpret and construct graphs related to projectile motion. The task sequence was developed in Desmos Classroom (now Amplify Classroom).

The design of the task sequence was informed by suggestions from previous research. First, it employed a real-world context, projectile motion, that could serve as a meaningful reference for students as they engaged in mathematical reasoning (Czocher et al., 2022; Sokolowski, 2021b). Second, it included non-canonical tasks that presented quantities in unfamiliar ways. For example, in typical projectile motion problems, time is represented on the x -axis and height on the y -axis. In this task sequence, the axes were reversed, with height represented on the x -axis and time on the y -axis. This unconventional representation was intended to engage students in new reasoning processes, such as quantitative and covariational reasoning (Moore et al., 2014). Third, the sequence also aimed to promote students' engagement in emergent graphical shape thinking as they interpreted and constructed graphs (Moore & Thompson, 2015; Paoletti et al., 2023). Finally, the design utilized the affordances of technology to synchronize the animation of the physical phenomenon with its graphical representation (Ainsworth, 1999; Johnson et al., 2020; Pittalis et al., 2025). For instance, when the ball moved upward, the line segment representing its height became longer, and when the ball descended, the line segment became shorter. These features were intended to help students connect the motion they observed with its quantitative representation.

¹ The complete digital task sequence can be accessed online at <https://classroom.amplify.com/activity/69061b958b3deaa21d53e9ef>

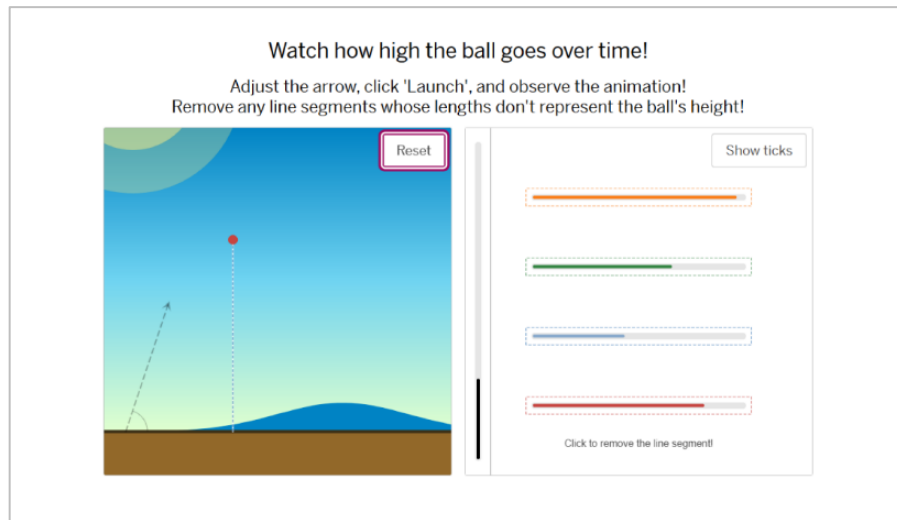


Figure 1. Screen Showing the Launch Activity Where Students Select a Line Segment Representing the Ball's Height Over Time

Within this sequence, the Height-Time Relationship Task consisted of three interactive screens that guided students to explore relationships between height and time during the motion of a launched ball. On the first screen (Figure 1), students could adjust the length and direction of an arrow to launch a ball. As the ball moved through its trajectory, they were asked to observe its height over time and to choose one of four line segments that best represented the ball's changing height. To support decision-making, students could eliminate the options one by one until only a single line segment remained.

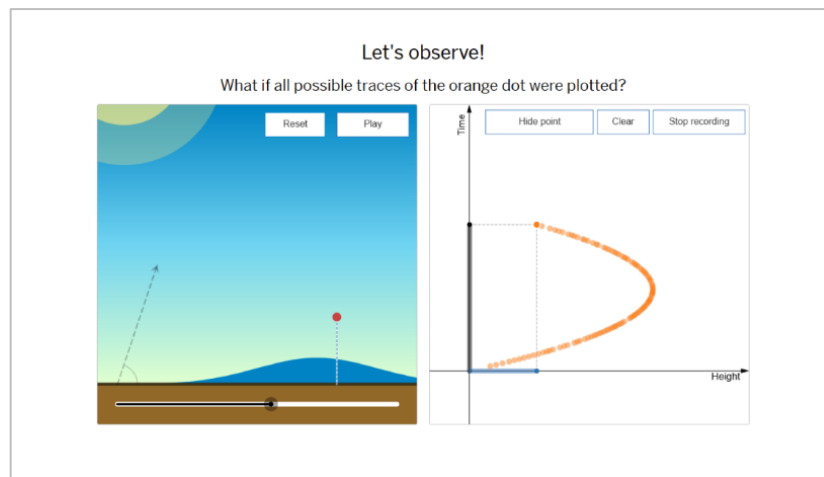


Figure 2. Screen Showing the Dynamic Relationship Between Height and Time Using Moving Line Segments

On the second screen (Figure 2), students again launched the ball and observed how its height changed over time. In this activity, the two quantities, height and time, were represented as the lengths of line segments along the x - and y -axes. Students could represent the relationship between these quantities as a moving point whose motion was constrained by the two line segments on the axes. They also had

the option to trace the path of the moving point, allowing them to visualize the trajectory it followed.

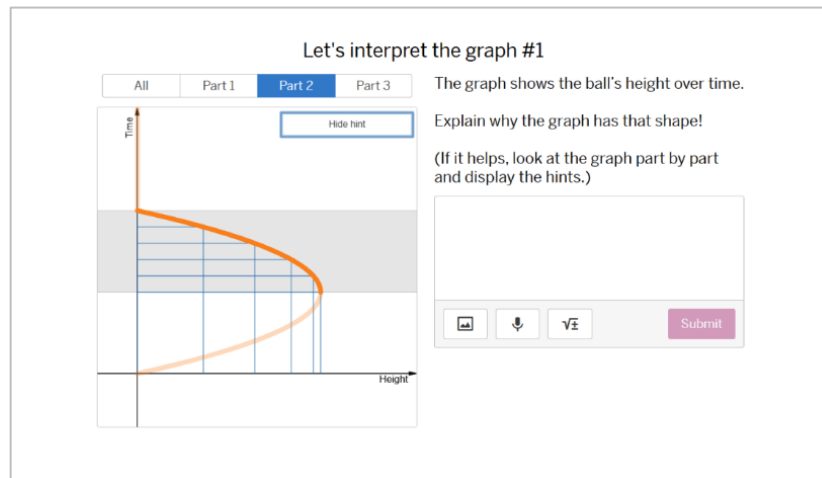


Figure 3. Graph Interpretation Screen Where Students Analyze the Ball's Height-Time Graph

The third screen (Figure 3) displayed a graph showing the height of the ball as a function of time and prompted students to interpret the shape of the graph. Students could analyze the graph in sections and were offered hints consisting of several equally spaced points on the y-axis, along with their corresponding points on the x-axis. These hints supported students in connecting graphical features to the quantitative relationships represented.

Analysis

During data collection, the two students sat side by side and worked collaboratively on a single laptop to complete the task. TR sat in front of them to facilitate the teaching experiment. While the students worked, their laptop screen was recorded using screen recording software, and their facial expressions were captured using the built-in webcam. A separate camera positioned behind them recorded their gestures and audio. All recordings were synchronized into a single composite video to support detailed analysis. Based on this video, we selectively transcribed the dialogue between TR and the students, along with the students' gestures, focusing on their activity on the third screen of the task. In particular, we focused on coverbal gestures, or gestures produced in coordination with speech, as these often convey meanings that complement verbal expressions and reflect students' emerging reasoning processes (Kendon, 2000; Kong et al., 2017; Paneth et al., 2024).

In analyzing the data, we first identified instances in the students' activity that provided evidence of their covariational reasoning as they engaged with the third screen. This screen was chosen because it was where the students developed their understanding of linear and quadratic relationships through graph interpretation. Second, we coded these instances using Thompson and Carlson's (2017) covariational reasoning framework. To strengthen the reliability of our analysis, we maintained a clear evidentiary trail that linked the data and our interpretations directly to the research questions. Finally, we connected the students' covariational

reasoning with how they constructed understandings for linear and quadratic relationships.

Findings and Discussion

This section presents the activity of Fania and Bianca as they engaged with the third screen of the Height-Time Relationship Task (Figure 3). The findings are reported chronologically to trace the shift in their reasoning. First, we describe how the students interpreted what the graph was composed of without yet connecting it to the covarying quantities it represented. Second, we examine their emerging understandings of the two covarying quantities represented in the graph. Finally, we present how their covariational reasoning developed as they compared the graph with a linear function graph.

Interpreting the Structure of the Graph

When Fania and Bianca opened the third screen, TR asked them to describe what the displayed graph represented. Responding to this prompt, Fania said:

“Because it’s like a collection of recorded data. Uh, what is it... possibilities. A trace, like a record of all the possible points where the points could be.”

We interpreted Fania’s understanding as being influenced by her experience on the previous screen (Figure 2). On that screen, she had observed how a graph representing the ball’s height over time was formed as a trace of a moving point whose motion was determined by the quantities it represented, namely height and time. Based on her statement, we infer that Fania conceived of the graph as traces of a point whose position was determined by the two varying quantities, the ball’s height and time. This interpretation of a graph as a trace of dynamic quantities is consistent with the perspectives suggested by Moore and Thompson (2015) and Paoletti et al. (2023).

TR then asked what shape the graph had. Fania responded:

“Like a half circle, curved, kind of oval [makes an oval gesture with her right thumb and index finger], and then it’s straight [uses her left hand to make a vertical line gesture].”

Bianca agreed with Fania’s interpretation. Their description of the graph’s shape was notable for two reasons. First, neither of them referred to it as a parabola, which suggests that the graph appeared novel to them. Second, their use of the term half oval to describe its form indicates that they drew on a familiar visual shape, likely a horizontally oriented half oval, to describe what they observed.

Constructing Meanings for Covarying Quantities

TR then invited Fania and Bianca to focus more closely on interpreting the shape of the graph. Specifically, TR asked why the graph appeared as a half oval at first, and was then followed by a vertical line. This question initiated the discussion presented in Table 2.

Table 2. Excerpt of Students' Discussion When Interpreting the Shape of the Graph

Speaker	Transcript
Fania	Mmm, maybe it's also affected by height. Because at the beginning, it starts from below [places right hand low], then it's thrown [makes a gesture of throwing a ball upward]. Since it's thrown, the height on the graph moves to the right. At a certain point, mmm, it comes back down because it's pulled by gravity [uses hand to trace the motion of a ball going up and down like a parabola]. So it comes back, and the graph moves to the upper left [uses right hand to make a diagonal gesture upward to the left]. That means the ball is going down [mimics a falling motion with her hand]. Then, when it reaches the ground, there's no more change in the ball's height, but time keeps moving, so the graph becomes a straight line.
TR	Bianca, anything to add?
Bianca	[Shakes her head] No, it's the same.

Based on the discussion in Table 2, Fania was able to describe how the quantities of time and the ball's height changed together. In doing so, she coordinated the physical situation, the motion of the ball over time, with the graph that represented it. For instance, she associated the upward-left segment of the graph with the moment when the ball was descending. This interpretation provides strong evidence that she was able to make meaningful sense of the graph and engage in covariational reasoning. Rather than construing the coordinate system spatially, which is a common tendency among students who interpret graphs as literal depictions of physical trajectories (Clement, 1989; Hadjidemetriou & Williams, 2002; Paoletti, Lee, et al., 2022), she conceptualized it quantitatively, with height represented on the x-axis and time on the y-axis. Within this understanding, she appropriately interpreted the upward-left segment of the graph as representing a decrease in height as time progressed, corresponding to the ball's downward motion. However, there was no evidence that she constructed a multiplicative object that explicitly paired time and height values. Therefore, we infer that she was engaging in covariational reasoning, particularly at the stage of gross coordination of values.

Shifts in Covariational Reasoning through Comparison with a Linear Graph

To promote more advanced covariational reasoning, TR invited Fania and Bianca to compare the graph on the third screen with a graph that the TR drew on the whiteboard. On the whiteboard, TR sketched a graph that followed the same overall pattern previously described by Fania: first extending upward to the right, then upward to the left, and finally continuing with a vertical line upward. However, unlike the digital graph, all parts of TR's graph followed linear patterns (Figure 4).

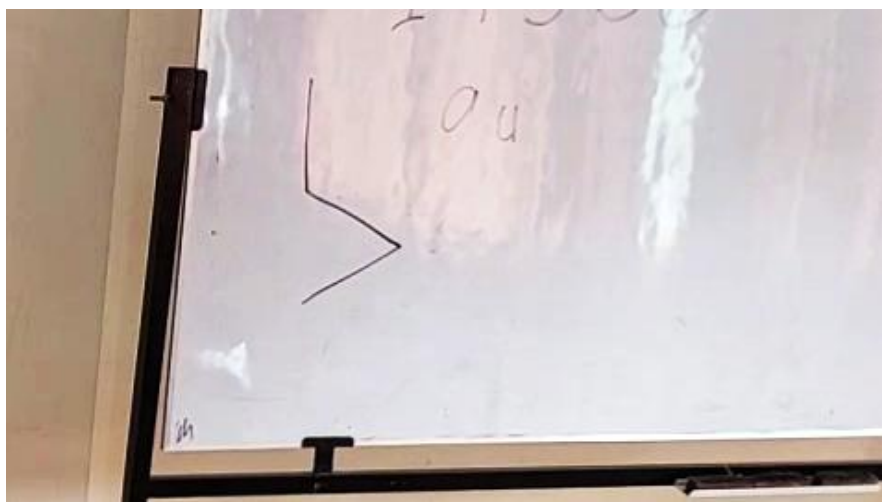


Figure 4. The Graph Drawn by TR on the Whiteboard

TR then asked why the graph on the third screen appeared curved rather than composed of straight segments, as in Figure 4. This question prompted Fania and Bianca to interpret TR's graph and led to the discussion presented in Table 3.

Table 3. Discussion Comparing the Curved and Linear Graphs

Speaker	Transcript
Fania	If it's diagonal, if it's straight like that [pointing to the TR's graph on the whiteboard], that means the speed is constant.
Bianca	Yes.
Fania	Every second it--
Bianca	Every second it--
Fania	Same.
Bianca	Same.

Based on Table 3, Fania and Bianca identified the key characteristic of the graph drawn by TR, namely that it represented a linear function. They interpreted that such a graph depicts two quantities whose average change is constant. In this reasoning, they were not only engaged in covariational reasoning but also made use of the ratio between the change in one quantity, the ball's height, and the change in the other quantity, time. Specifically, they used "every second" as the unit of time. Therefore, we infer that they were engaged in covariational reasoning at least at the stage of chunky continuous covariation.

After that, TR asked Fania and Bianca to interpret the graph on the third screen again, but this time part by part, using the hints provided. The following excerpt shows Fania's interpretation of the first part of the graph, which represents the ball's height over time as it moves upward.

"Oh, that means within the same unit of time, the height isn't necessarily the same. If the graph were a straight diagonal line like that [pointing to the graph on the whiteboard], then within the same time interval, the height would always be the same, so the differences between intervals would be equal. But because this graph curves, that

means for the same unit of time, the height varies. So, in the first second, for example, it's still far apart because it's just been thrown [making a throwing gesture from bottom to top], so the height increases quickly. In the second second, it gets slower [gesturing smaller intervals with her right thumb and index finger]. So the graph becomes more compact, see [gesturing again to show smaller intervals with her left hand]. In the third second, it's even smaller because it slows down again [repeating the gesture with her right hand]. In the fourth second, smaller again [same gesture]. Until finally it stops at the top [pointing upward with her right hand], then goes down again [mimicking the downward motion of the ball]."

TR then invited Bianca to add to or restate Fania's explanation in her own words. Bianca responded as follows:

"So, if the diagonal is a bit curved, that means each second has a different height, not the same. If it's a straight line like this [moving her right hand upward diagonally to form a straight line], that means every second the height is the same, like it goes straight up [repeating the same gesture]. And, what's it called, when the distance between them gets smaller [gesturing smaller intervals with her right thumb and index finger], that means it's about to go down."

Based on Fania and Bianca's explanations, they contrasted the graph on the third screen with the linear graph drawn on the whiteboard. Specifically, they compared how one quantity changed while the other varied at a constant rate. They interpreted that the ball's height changed by progressively smaller amounts as time increased uniformly. Fania referred to "the first second," "the second second," "the third second," and "the fourth second" to indicate that she was considering equal units of time, even though the intervals shown by the hints on the third screen did not necessarily represent one second. Thus, we infer that both students engaged in covariational reasoning and that their reasoning showed a shift toward a more sophisticated coordination of the two varying quantities. Whereas earlier they demonstrated reasoning at the stage of gross coordination of values, they now exhibited reasoning characteristic of the chunky continuous covariation stage.

Fania and Bianca applied similar reasoning when interpreting the second part of the graph, which represented the ball's descent. Their explanations reflected covariational reasoning at the stage of chunky continuous covariation. TR then invited one of them to interpret the final segment of the graph. Bianca responded as follows:

"This means that the ball is no longer moving and has stopped, but time keeps passing." [She moved her right hand upward to illustrate the increase in time along the y -axis.]

Bianca's explanation indicates her understanding of the vertical line segment on the graph. She interpreted the vertical segment as representing a constant height while time continued to progress. In doing so, she no longer referred to discrete

time units to explain the ball's motion but instead expressed that the height remained unchanged as time flowed continuously. We therefore infer that she engaged in covariational reasoning at the smooth continuous covariation stage, demonstrating a more refined coordination of continuously varying quantities.

Discussion

We have shown how Fania and Bianca's covariational reasoning developed as they interpreted the relationship between height and time in the context of projectile motion. Our findings indicate that prompts encouraging students to compare linear and quadratic relationships can foster more sophisticated forms of covariational reasoning. Moreover, such reasoning supported the students in constructing meaning for a linear relationship as one in which the change in one quantity remains constant when the change in the other quantity is constant. In other words, they understood a linear relationship as one characterized by a constant rate of change.

Building on this understanding, the students developed meanings for the relationship between height and time in projectile motion: that the change in height becomes smaller as the ball rises and larger as it falls. Although this understanding alone does not fully characterize the quadratic relationship that models projectile motion, it may serve as a productive entry point, or in Harel's (2013) terms, an intellectual need, for exploring additional characteristics of quadratic relationships. Thus, our study contributes to the growing body of research that employs covariational reasoning as a lens for supporting students in making sense of different types of mathematical relationships (Hohensee et al., 2024; Paoletti & Vishnubhotla, 2022; Sokolowski, 2021a; Wilkie, 2020).

In our findings, Fania and Bianca engaged in covariational reasoning both when imagining the motion of the ball (whether rising, falling, or stationary) and when interpreting the graph. We highlight several important points regarding this. First, the opportunity to observe the physical situation helped them construct the involved quantities and the relationships between them. In our study, this was supported by the technological affordances that allowed the situation to be displayed dynamically while simultaneously showing the corresponding quantitative representations. This aligns with prior studies demonstrating the role of technology in promoting covariational reasoning (Johnson et al., 2020; Martínez-Sierra & Villadiego Franco, 2025; Pittalis et al., 2025). Second, the students' understanding of the graph as a representation of covarying quantities, consistent with the perspective suggested by Moore and Thompson (2015), supported their engagement in covariational reasoning. This finding resonates with previous research highlighting the importance of helping students view graphs as representations of covarying quantities rather than as static shapes (Moore, 2021; Paoletti, Hardison, et al., 2022; Paoletti, Stevens, et al., 2024). Finally, our study also shows that the use of non-canonical graphing tasks can be effectively implemented with middle school students, providing them with opportunities to engage in novel and productive forms of mathematical reasoning (Moore et al., 2014, 2019). In addition, the use of such tasks in our study provided strong evidence for assessing whether students engaged in covariational reasoning when interpreting graphs. The non-canonical design enabled us to distinguish whether

students were reasoning within a spatial coordinate system or constructing a quantitative coordinate system as they analyzed the projectile motion context.

Future research could extend this work by exploring students' covariational reasoning in analyzing other representations of projectile motion, such as horizontal distance versus time. In doing so, students' understanding of height-time and horizontal distance-time relationships may support their reasoning about parametric representations of projectile motion. Another promising direction is to further investigate how students develop an understanding of quadratic relationships as involving a constant rate of change of the rate of change.

This study has several limitations. The analysis focused only on the students' activity on the third screen, so it does not capture how their reasoning may have been influenced by earlier screens of the same task. However, this focus still provided meaningful insights into how covariational reasoning supports students in developing an understanding of linear and quadratic relationships. In addition, the study involved only two students, which limits the generalizability of the findings, as other students may develop different ways of understanding these relationships.

Conclusion

This study has illustrated a developmental shift in how middle school students engage in covariational reasoning when interpreting relationships between height and time in a projectile motion context. By comparing linear and quadratic relationships, students developed an understanding of constant and varying rates of change, which supported their construction of meaningful connections between quantities. The findings highlight the potential of technology-enhanced, non-canonical graphing tasks for fostering students' covariational reasoning in dynamic situations.

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CHALLENGES OF JUNIOR HIGH SCHOOL STUDENTS IN SOLVING MINIMUM COMPETENCY ASSESSMENT ITEMS

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Received: 10 September 2025; Accepted: 5 November 2025

Abstract

The ability to solve Minimum Competency Assessment (AKM) questions is one of the key competencies expected in mathematics learning. However, there are still limited studies that investigate and explore student difficulties in solving such questions. This study aims to identify the forms and causes of problems faced by students in solving AKM questions. This study employs an exploratory qualitative method using 21 eighth-grade students from a Junior High School in Banda Aceh as participants, who were selected based on their errors in answering AKM questions. The instruments used are test questions and interview guidelines. The data collection techniques used are tests and interviews. Data analysis techniques followed the model of Miles, Huberman, and Saldaña, which consists of data condensation, data display, and conclusion drawing/verification. The results show that students struggle to interpret question statements, develop solution strategies, and verify their answers. These challenges stem from insufficient mastery of fundamental mathematical concepts, unfamiliarity with reasoning-based AKM questions, and gaps in prerequisite knowledge. These insights help teachers recognise the nature and causes of students' difficulties, allowing them to craft targeted strategies to improve AKM performance. This study offered a deeper understanding of students' obstacles, supporting more effective mathematics instruction.

Keywords: AKM questions, mathematics learning, student difficulties

Introduction

Mathematics is a science whose objects are abstract in nature. It requires a way of thinking that connects relationships arranged logically and structurally (Hudojo, 2003). This requires someone with mathematical knowledge to use and develop reasoning.

The results of the PISA evaluation support the statement that the numeracy skills of students in Indonesia are still relatively low. During 18 years of participating in the Programme for International Student Assessment (PISA), Indonesia has not shown satisfactory results. Qadry et al (2022) stated that the PISA results reflect the low achievement of Indonesian students in mathematics. In PISA 2018, Indonesian students' average mathematical literacy score was only 379, far below the international average of 500 (OECD, 2023). In fact, the 2022 PISA results declined to 366, while the OECD country average reached 472. This condition reflects that the literacy skills of Indonesian students still require serious attention



(Fitra et al., 2024). Looking at the dimensions of mathematics content tested, Indonesian students scored an average of 375 for numbers, 392 for algebra, 377 for geometry, and 379 for data and probability (Ariyanti & Setiawan, 2019).

Since 2016, the Ministry of Education and Culture has been striving to foster a literacy culture by launching the National Literacy Movement (Kemendikbud, 2021). In 2021, Kemendikbud implemented a new National Assessment or Minimum Competency Assessment (AKM) program. The AKM system refers to international standards, namely PISA and TIMSS, as assessment benchmarks (Sherly et al., 2020). This assessment is conducted to obtain information to improve the quality of learning, hoping also to improve student learning outcomes. The primary focus of AKM is on fulfilling students' reading and numeracy literacy skills (Cahyana, 2020).

Numeracy skills are critical to apply in everyday life because they make it easier for someone to plan, calculate, and interpret data (Kemendikbud, 2021). Numeracy skills require students to be able to solve problems. The OECD (2023) states that numeracy skills encompass understanding and applying concepts in real-world contexts to solve problems logically and effectively. This problem-solving ability will guide students to think critically to find the correct methods and solutions to solve problems (Widiasih et al., 2018). However, the fact that Indonesian students' scores fall into the low category poses a new problem for education in Indonesia. Indonesian students must master all content tested in the AKM, including data and probability, numbers, algebra, and geometry (Kemendikbud, 2021). The low scores obtained are due to students' inability to solve mathematical problems, which is influenced by the difficulty students experience in working on the questions given (Farhan & Zanthly, 2019).

However, various studies have shown that students struggle to solve AKM questions. Research by Novalia and Rochmad (2017) on difficulties in solving questions shows that many students do not understand the questions and encounter obstacles at the planning stage, which leads to incorrect final answers. Sholehah et al.'s (2022) research on AKM problem-solving abilities shows that students are not yet proficient in solving AKM numeracy problems. Several studies indicate that little research has explored the difficulties and causes of students' problems in solving AKM problems. Previous research by Akhidayati et al., (2024) at SMP Plus Hidayatul Mubtadiin showed that students experienced difficulties in three stages of AKM problem solving, namely: (1) formulating problems, due to a lack of understanding of the questions and identifying relevant information; (2) applying mathematical concepts, resulting in obstacles in writing down the steps to solve the problem; and (3) interpreting the results, due to not being accustomed to relating the solution to a real-world context.

Based on previous studies' findings, research on students' difficulties in solving AKM problems is fundamental. If students' difficulties in solving AKM problems are not addressed immediately, it will continue to impact Indonesian students' scores, which remain in the low category. To overcome this, support from various parties is needed, one of which is the important role of teachers in identifying the root causes of students' difficulties in solving AKM problems, which require problem-solving skills. One technique that can be used to analyse students' problem-solving difficulties is Polya's problem-solving steps. Polya (1973) states that problem solving has four stages, namely: (1) understanding the problem; (2)

determining the solution strategy; (3) implementing the strategy to solve the problem; and (4) checking the answer. If students do not follow these problem-solving steps correctly, it can be said that they are difficulties in solving problem-solving questions, which means that students cannot solve one or more problem-solving steps (Latifah & Afriansyah, 2021).

Method

This study employs a qualitative descriptive approach. The research participants were 21 eighth-grade students from a Junior High School in Banda Aceh. Data were collected using the AKM test instrument, adopted from Pusmenjar (Assessment and Learning Centre), and accessible through the website <https://pusmenjar.kemdikbud.go.id/akm>. The test consisted of four questions covering geometry, data and uncertainty, algebra, and numbers. The test was a written test in the form of open-ended questions. The open-ended questions were chosen to determine students' problem-solving steps according to Polya's problem-solving method. Data analysis followed the model of Miles, Huberman, and Saldaña (2014), which includes data condensation, data display, and conclusion drawing/verification. Test answers were analysed based on Polya's problem-solving steps, followed by interviews to explore the causes of students' difficulties in solving AKM questions. Interview participants were selected based on their errors in answering the minimum competency assessment test questions given at the beginning. The researcher initially asked several prepared questions during the interview, but these questions could be developed according to the participants' conditions. The following are indicators of difficulty based on Polya's problem-solving steps (Polya, 1973).

Table 1. Problem-Solving Difficulty Indicators

No	Type of Difficulty	Indicators
1	Difficulty understanding the text of the question	a. Inability to remember names, terms, and data contained in the text of the question. b. Inability to explain the question text in one's own words. c. Inability to identify known data and requested data.
2	Difficulty making plans	a. Inability to make connections, apply concepts, and use formulas to solve problems. b. Inability to translate the question text into a mathematical model or form.
3	Difficulty executing plans	a. Inability to perform mathematical operations correctly.
4	Difficulty checking the correctness of results	a. Inability to accurately and correctly conclude answers. b. Students do not double-check their work process.

Findings and Discussion

Based on the test results, two students were selected to participate in the study. They were chosen based on their mistakes in answering the test questions

given at the beginning. They were then interviewed to reveal the difficulties they experienced based on Polya's problem-solving steps.

Table 2. Selection of Interview Participants

No.	Participant
1	S1
2	S4

There were four questions on the test. Below are the answers from two students selected based on the number of mistakes they made when answering the AKM questions.

Solving AKM Geometry Problems

1) Participant 1

1. Dik: Berat badan = 54 kg
 Banyak dg 30 = $54 : 30 = 1,8$
 Dit: Jika Santi berolah raga selama 60 berapakah jumlah air yg dibutuhkan Santi pada saat itu
 $= 1,8 + 0,35 \times 2$
 $= 1,8 + 0,70$
 $= 1,78 \text{ ml}$
 Jadi jumlah air yg dibutuhkan oleh Santi untuk berolah raga selama 60 menit adalah 1,78 ml

Figure 1. Participant 1's Answer Sheet for Geometry Content Questions

The following are excerpts from the interview with Participant 1.

P₀₁ : What do you understand about the question? Explain it in your own words.

S1₀₁ : Santi exercised for 60 minutes, then how did she get water?

P₀₂ : What concept will you use to solve this problem?

S1₀₂ : It seems like the concept of addition, there is also division.

P₀₃ : Here, the solution is 0.35×2 . Where did that come from, and why is it multiplied by 2?

S1₀₃ : It is multiplied by 2 because the question asks for 60 minutes, so 0.35×2 equals 0.7.

P₀₄ : How did you get the answer 1.78?

S1₀₄ : The number 1 is lowered, then 70 is added to 8, which equals 78.

P₀₅ : Did you check your own answer?

S1₀₅ : No, I didn't.

Based on Figure 1 and the interview results, participant 1 had difficulty understanding the question text because he could not explain the text in his own words from statement S1₀₁. In statement S1₀₂, the participant appeared uncertain about the concept to be used to solve the problem. The participant also had difficulty planning because they could not perform mathematical operations correctly,

namely when completing the addition in decimal form, as seen in Figure 1 and statement S1₀₄. The participant stated the result of 1.78 was obtained by subtracting 1, then adding 70 and 8. This caused the participant to experience difficulties due to their weak basic mathematical concepts. In addition, participants also appeared to have difficulty checking the correctness of the results, indicated by errors in solving the problems and not rechecking the process based on statement S1₀₅.

2) Participant 4

Handwritten work by Participant 4:

$$\begin{aligned}
 &2.) \text{ Dik : berat badan} = 34 \text{ kg} \\
 &\quad \text{angka} = 30 \\
 &\quad \text{bagilah} = 54 : 30 = 1.8 \\
 &\text{Dik : ditambah} = 0.35 \\
 &= 1.8 + 0.35 + 2 \\
 &= 1.8 + 0.07 \\
 &= 1.78
 \end{aligned}$$

Figure 2. Participant 4's Answer Sheet for Geometry Content Questions

The following are excerpts from the interview with Participant 4.

- P₀₁ : What do you understand the question to mean?
 S4₀₁ : Calculate the amount of water added for Santi after exercising.
 P₀₂ : What concept will you use to solve this problem?
 S4₀₂ : I think the concept of measuring the amount of water.
 P₀₃ : Here it says 0.35×2 . Where does that come from, and why multiply by 2?
 S4₀₃ : Hm, why is that... I forgot why it's multiplied by 2.
 P₀₄ : How did you get the result of 1.8 plus 0.07?
 S4₀₄ : Hm... I added them up as usual. Also, because there are two digits after the decimal point, the result is 1.78.
 P₀₅ : What is your conclusion?
 S4₀₅ : So, Santi needs 1.78 litres of water.

Based on Figure 2 and the interview results, participant 4 had difficulty understanding the text of the question with statement S4₀₁. Low text comprehension skills prevented the participant from connecting the information. This was because the student was not accustomed to solving problems that required reasoning. Participants appear to have difficulty making plans, as seen in statement S4₀₂. Participants have difficulty implementing plans because they cannot perform mathematical operations correctly, as seen in Figure 2, when adding 1.8 and 0.7. Participants stated that the addition process using decimals did not follow the decimal addition rules, as seen in statements S4₀₃ and S4₀₄. Participants appeared to have difficulty checking the correctness of the results, as seen in their inability to correctly and accurately conclude the answers, as seen in S4₀₅.

Solving AKM Data Content and Uncertainty Problems

1) Particaipant 1

2. Dik: berwarna hitam = $\frac{1}{24}$
 bagian putih = $\frac{1}{12}$
 bagian merah = $\frac{1}{8}$

Dit: bagian berwarna hijau dan kuning

~~$\frac{1}{24} + \frac{1}{12} + \frac{1}{8} = \frac{1}{24} + \frac{2}{24} + \frac{3}{24} = \frac{6}{24}$~~

~~$\frac{1}{24} + \frac{1}{12} + \frac{1}{8} + x = \frac{24}{24}$~~

$\frac{1}{24} + \frac{1}{12} + \frac{1}{8} + x = \frac{24}{24}$

$\frac{1+2+3+x}{24} = \frac{6}{24} + x = \frac{24}{24} = \frac{4}{1}$

Figure 3. Participant 1's Answer Sheet for Data Content and Uncertainty Questions

The following are excerpts from the interview with participant 1.

P01 : What do you know about the term “wheel divided into 24 parts”?

S101 : There is a wheel that has 24 parts.

P02 : What do you understand from this question? Explain it in your own words.

S102 : The wheel has black, white, and red sections, and we know how many of each there are, but we don't know how many green and yellow sections there are.

P03 : Why is it $1+2+3+x$?

S103 : The denominators are made equal, then the result is added up to 6. Then it is simplified by dividing by 6, so the result is $\frac{1}{4}$. Because it is moved to the right, it is reversed.

P04 : Why does it have to be reversed?

S104 : Because to find the value of x , it is moved to the right.

P05 : So, what is the final conclusion of your answer?

S105 : There are four green parts and four yellow parts.

Based on Figure 3 and the interview results, participant 1 had difficulty understanding the text of the question, making plans, implementing plans, and checking the correctness of the results. This can be seen from the participant's inability to remember the terms in the text of the question from statement S101 and the participant's misinterpretation of the question's meaning as seen from statement S102. The participant appeared to have difficulty implementing the plan, as indicated by errors in the algebraic operation process, namely mistakes in determining the value of x . The participant misunderstood the process of transferring terms to determine the value of x . The participants had difficulty because they had not mastered the previous or prerequisite material. The previous

material here refers to algebraic operations learned in the 7th grade of junior high school. Participants also had difficulty checking the correctness of the results, as indicated by their inability to accurately and correctly conclude the answers according to the results of interview S105, in which participants stated conclusions for the yellow and green parts, which were not in accordance with the questions asked. In addition, because the algebraic process was incorrect, the final answers were inaccurate.

2) Participant 4

The image shows handwritten mathematical work. At the top, it says "2> Dit = berwarna hitam = 1/24", "berwarna putih = 1/12", and "berwarna merah = 1/8". Below this, it says "Dit... ?". Then, there are several equations: $\frac{1}{24} + \frac{1}{12} + \frac{1}{8} = \frac{6}{24}$, $\frac{1}{24} + \frac{2}{12} + \frac{3}{8} = \frac{6}{24}$, $\frac{6}{24} = \frac{x+1}{24}$, $x+1=24$, $x=24-1$, $x=23$, $x+2=24$, $x=24-2$, $x=22$, $x+3=24$, $x=24-3$, $x=21$, and $300=3$.

Figure 4. Participant 4's Answer Sheet for Data Content and Uncertainty Questions

The following are excerpts from the interview with participant 4.

- P₀₁ : What do you know about the term "wheel divided into 24 parts"?
 S4₀₁ : The wheel consists of 24 parts.
 P₀₂ : In your opinion, how would you shade 1/24?
 S4₀₂ : The one that is not shaded is one, and the one that is shaded is 24.
 P₀₃ : Why is $x+1$ equal to 24?
 S4₀₃ : It equals the denominator (points to the answer sheet).
 P₀₄ : So, is $24-1$ equal to 25? Is it added or subtracted?
 S4₀₄ : It could be added. Because $24-1$ equals 23. So it is added.
 P₀₅ : So, what is the final conclusion of your answer? Why?
 S4₀₅ : There are 3 in total, because (pauses)

Based on the interview results, participant 4 could not remember the terms in the question text, as seen in statement S4₀₁. The participant also appeared unable to identify the known data and the data being asked, as seen in Figure 4. The participant also appeared unable to determine the shaded and unshaded parts, as seen in the interview results S4₀₂. Participants also had difficulty planning, as indicated by errors in performing mathematical operations, as seen in statements S4₀₃ and S4₀₄. Participants did not answer the reason for the conclusion, as seen in statement S4₀₅.

Participants experienced difficulties because they did not fully understand the concepts of fractions and algebra due to their lack of mastery of the previous material. Participants misunderstood the shaded and unshaded parts of the wheel and were confused when completing the algebraic operations. In fact, the concepts of fractions and algebraic operations had been studied previously. Low problem-

understanding skills prevented participants from connecting the information they had.

Solving AKM Algebra Content Problems

1) Participant 1

3. Dik : Adik berusia 5 thn
 = Keluarga besar 15
 orang dewasa 7
 orang per topi 2.500.000
 uang 150.000,00
 Dit : Jumlah teman adik
 $150.000,00 \div 2.500.000 = 60.$
 $60 - 22 = 38$

Figure 5. Participant 1's Answer Sheet for Algebra Content Questions

The following are excerpts from the interview with Participant 1.

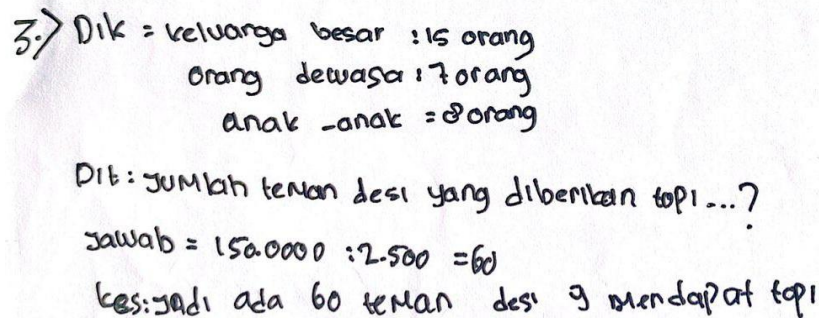
- P₀₁ : What method did you use for this question?
 S1₀₁ : First, I calculated the number of hats that could be bought, then subtracted the number of Desi's family members.
 P₀₂ : Have you ever seen or worked on a question like this?
 S1₀₂ : Never.
 P₀₃ : What does 150,000 divided by 2,500 mean? (points to the answer sheet)
 S1₀₃ : Since each hat costs 2,500, and Desi's mother has 150,000, she divides that by 60 to find out how many hats she can buy.
 P₀₄ : Why is it subtracted by 22? Do you think 22 is correct?
 S1₀₄ : Yes, because initially it was calculated as 15 plus 7 people, which equals 22.
 P₀₅ : So, what is your final conclusion?
 S1₀₅ : The number of hats for the younger sibling's friends is 38.
 P₀₆ : Are you sure about the answer 38?
 S1₀₆ : Yes, I am sure.

Based on Figure 5, participants wrote down the data they knew and were asked. Participants apparently misunderstood the question from the interview results, resulting in incorrect answers. Based on statements S1₀₃ and S1₀₄, participants also had difficulty making plans. Interview result S1₀₁ shows uncertainty about the method to solve the problem. In addition, participants seemed to have difficulty checking the correctness of the results, as seen in statement S1₀₅. Participants were confident in their solution and answers, but did not double-check their work before submitting it. This can be seen in statement S1₀₆.

Based on the interview results, low question comprehension skills prevented participants from connecting the information they had. This was because the participants were not accustomed to solving reasoning questions, which resulted in

them making incorrect connections that would be used to solve the questions. This statement can be seen from the results of interview S1₀₂, which stated that the participants had never seen or worked on this type of question before. This caused the participants to be unable to solve these questions correctly and accurately.

2) Participant 4



3. > Dik = keluarga besar : 15 orang
 orang dewasa : 7 orang
 anak-anak : 8 orang

Dit: Jumlah teman desi yang diberikan topi ...?

Jawab = $150.000 : 2.500 = 60$

Kes: jadi ada 60 teman desi yang mendapat topi

Figure 6. Participant 4's Answer Sheet for Algebra Content Questions

The following are excerpts from the interview with Participant 4.

- P₀₁ : What do you understand from number 3? Can you explain it in your own words?
- S4₀₁ : (Silence)
- P₀₂ : Do you know how to solve this problem?
- S4₀₂ : Just divide the amount of money.
- P₀₃ : This is 150,000 and 2,500; why are both divided?
- S4₀₃ : I just tried dividing it because it is both about money.
- P₀₄ : Why not subtract, add, multiply, or something else?
- S4₀₄ : If the others are subtracted, that could be the answer. I tried to find the multiplication, but the numbers are significant. If you add and subtract, the answer may be less.
- P₀₅ : Why is it less?
- S4₀₅ : Hm... I do not know.
- P₀₆ : Are you sure about your answer?
- S4₀₆ : Not really sure.

Based on the interview results, it appears that participant 4 had difficulty understanding the text of the question, as indicated by the participant's inability to understand the meaning of the question, as seen in S4₀₁, where the participant remained silent and did not answer the question. The participant also had difficulty making plans, as seen in the interview results S4₀₂ and S4₀₃, which stated that the participant seemed hesitant to make the connections in the text of the question. The participant was also confused about the calculation operations to solve the problem, as indicated in statements S4₀₄ and S4₀₅. The participant had difficulty carrying out the plan, as indicated by the participant's inability to complete the problem thoroughly. The participant only calculated the number of hats Ms Desi could buy, but did not calculate the number of hats that could be given to Desi's younger sibling's friends on the younger sibling's birthday. In addition, the participant had

difficulty checking the correctness of the results shown in Figure 6 and statement S4₀₆.

Based on the interview results, low problem comprehension skills caused participants to be unable to connect the information they had. This was because participants were not accustomed to solving reasoning problems, resulting in them making incorrect connections that would be used to solve the problem. This weak comprehension and reasoning ability caused participants to have difficulty solving this problem.

Solving AKM Number Content Problems

1) Participant 1

4. Dik: Diskon
 di toko Jaya baju 25% celana 10%
 di toko Andini Baju 20% celana 15%
 -//- Selaras Baju 15% celana 20%
 K-//- Bagus Fashion Baju 10% celana 25%
 Jwb. 1 = salah karena harga selisahnya itu 10%
 2 = salah karena yang paling mahal di toko Jaya 90.000

Figure 7. Participant 1's Answer Sheet for Number Content Questions

The following are excerpts from the interview with participant 1.

- P₀₁ : What do you know about the term “Jaya store 25% discount”?
 Please explain!
- S1₀₁ : It means that at the Jaya store, you only pay 25%.
- P₀₂ : What do you know, and what is being asked in the question?
- S1₀₂ : Hm...
- P₀₃ : How do you understand the question? Please explain it in your own words.
- S1₀₃ : Actually, I do not really understand question number 4.
- P₀₄ : Which part don't you understand?
- S1₀₄ : I do not understand the question, and I am confused about how to answer it.
- P₀₅ : Do you have any difficulties in completing questions like this?
- S1₀₅ : I'm confused because there's a lot of information and questions, and I don't know how to answer them, so I rewrote the question like this.
- P₀₆ : So, what is your final conclusion?
- S1₀₆ : Statement 1 is wrong because the difference is 10%, and statement 2 is wrong because the most expensive one in C = 10%.

Based on the interview results, participant 1 had difficulty understanding the text of the question, as evidenced by their inability to explain the text of the question in their own words. In accordance with statement S1₀₁, the participant stated that

the term “25% discount” at the Jaya store meant paying only 25%. In statement S1₀₂, the participant could not explain the known data and questions, but from Figure 7, the participant wrote down the known data. Participant 1 also had difficulty understanding the meaning of the question text, as indicated by statements S1₀₃ and S1₀₄, which show that the participant did not fully understand the meaning of question number 4. The participant also had difficulty making plans, as seen in the interview results S1₀₅, which stated confusion with the method of solution used in the question. The participant could not translate the text of the question into a mathematical model, as seen in Figure 7. In addition, the participant seemed to have difficulty checking the correctness of the results. In statement S1₀₆, the participant could not accurately and correctly summarise the answer.

Based on the interview results, poor comprehension skills prevented participants from connecting the information they had. This was because participants were not accustomed to solving reasoning questions. This was evident when participants stated that they did not understand the meaning of the questions and were confused about the steps to solve them. Weak comprehension and reasoning skills caused participants to have difficulty solving these questions.

2) Participant 4

① TOKO JAYA : $\frac{25}{100} \times 80.000 = 200.000 - 80.000$
 $= 180.000$

TOKO SELARAS : $\frac{15}{100} \times 80.000 = 120.000 - 80.000$
 $= 40.000$

① Alasan : karena harga setelah diskon Rp. 180.000. Jadi tidak sesuai dengan pernyataan.

Figure 8. Participant 4's Answer Sheet for Number Content Questions

The following are excerpts from the interview with participant 4.

- P₀₁ : What do you know about the term “difference” here?
 S4₀₁ : Difference means the difference between Jaya and Selaras stores.
 P₀₂ : What do you know, and what questions are asked in the problem?
 S4₀₂ : The original price and the discounted price. Jaya Store offers a 25% discount on clothes... (silence)
 P₀₃ : What do you understand from the first statement in the table?
 S4₀₃ : The difference in the price of one piece of clothing between the Jaya and Selaras stores.
 P₀₄ : How do you think the difference should be calculated?
 S4₀₄ : Hm...
 P₀₅ : Why didn't you do statement 2?
 S4₀₅ : I ran out of time yesterday.

- P₀₆ : Do you understand the meaning of question 2?
S₄₀₆ : Hm... I understand it, but do not quite understand how to find it.
P₀₇ : What is the final conclusion of your answer?
S₄₀₇ : Hm... I do not know because I did not do it. If we conclude from statement a, the price after the 180,000 discount does not match the statement table.

Based on the answer sheets and interview results, participant 4 had difficulty understanding the text of the questions. In statement S₄₀₁, the participant could not remember the terms in the question's text. In addition, in statement S₄₀₂, the participant appeared unable to identify the known data and the data being asked for. Participants could also not explain the question text in their own words, as seen in statement S₄₀₆. Participants did not complete statement 2 because they ran out of time, as seen in statement S₄₀₅. Participants had difficulty planning because they were unable to make connections and concepts that would be used to solve the problem. Participants could also not perform mathematical operations correctly, as seen from the errors in multiplication and subtraction operations, as seen in Figure 8. Participants had difficulty checking the correctness of the results, as seen in statement S₄₀₇, namely, they were unable to correctly and accurately conclude the answers.

Based on the interview results, participants could not perform mathematical operations correctly, as evidenced by errors in performing percentage subtraction. Participants made mistakes in subtraction, which led to incorrect answers. This was due to their weak basic mathematical concepts. Participants also stated that they did not complete statement 2 because they ran out of time. Another reason was that their problem-solving skills were still low, causing them to experience difficulties when completing the problems.

Conclusion

The study's conclusions show that the types of difficulties experienced by students are difficulty understanding the text of the questions, difficulty making plans, difficulty implementing plans, and difficulty checking the accuracy of the results. The most dominant difficulties are understanding the text of the questions, making plans, and checking the accuracy of the results. The causes of students' difficulties are that they have not mastered basic mathematical concepts well, such as equations in algebra, low mastery of basic calculation skills, unfamiliarity with reasoning questions, such as AKM with real contexts, and low skills in understanding questions. Another cause of difficulty is that students have not mastered the previous material or prerequisite material. Teachers can help students by reinforcing basic concepts, familiarising them with contextual exercises, and guiding them through problem-solving steps to prepare them for AKM better. The suggestion for readers and other researchers is to accustom students to solving AKM questions and to guide students who experience difficulties. In addition, using concepts related to converting real-world contexts into mathematical forms or vice versa will be strengthened to overcome students' difficulties.

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DEVELOPMENT OF VALUE-BASED HYPERCONTENT E-LEARNING MODULES TO IMPROVE THE CHARACTER OF HIGH SCHOOL STUDENTS

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Received: 31 October 2025; Accepted: 6 November 2025

Abstract

The moral crisis occurring among the younger generation today, especially among high school students, is a major challenge for the world of education. The impact of this moral crisis is felt in the increase in negative behavior that deviates from the norms that apply in society. Cases of bullying, vandalism, swearing, and foul language are often encountered. Various steps need to be taken, one of which is character building through instilling basic values in students. This study aims to develop a hypercontent-based e-learning module based on character values to support the holistic character building of high school students. The model used was the ADDIE Model (Analysis, Design, Development, Implementation, Evaluation), which was adapted to the learning needs in the digital age. Students of Pangudi Luhur St. Yosef Surakarta High School in grade XII were selected as research subjects using purposive sampling. This module was designed to be interactive and integrated with basic values, especially "defending the weak," which are presented through dynamic and modular hypermedia content. The material was compiled based on an independent curriculum and was directly related to the context of students' daily lives. The results of the study show that the developed e-module has met the criteria for material feasibility and media feasibility, as well as the practicality test for character building. The results of the e-module development applied to high school students show that the use of value-based hypercontent e-modules are considered effective, as demonstrated by the cognitive test results with 100% achievement and an average score of 87. Therefore, this e-module has become a strategic tool in achieving the goal of sustainable character education. This research contributes to the development of digital teaching materials oriented towards 21st-century skills and provides a concrete platform for schools to implement character-based education effectively.

Keywords: hypercontent e-module, student character, value-based education

Introduction

The decline in character among the younger generation today is very noticeable, especially among high school students. We often hear of cases of violence, rude language, swearing, even destruction of public places, bullying, and vandalism committed by teenagers, most of whom are high school students.



The biggest challenge for the world of education is how to instill good character in students, especially high school students. Character building is urgently needed as a solution. The Merdeka Curriculum, with its deep learning approach, sets out various efforts that can be made to instill character in students, such as character building activities, basic leadership and character training, integration of character values in subjects, and character building through co-curricular activities that must equip students with eight graduate profiles, namely faith and devotion to God Almighty, citizenship, creativity, critical thinking, communication, and health.

Based on initial observations, the implementation of character building in various high schools has been limited due to the lack of guidebooks or manuals that serve as a basis for character building. Some private schools rely on instilling values that are characteristic of their school or the characteristics, vision, and mission of the owning foundation. Developing modules to equip students so that they can easily learn and strengthen their character is very necessary. With the rapid development of technology, students are becoming more familiar and comfortable with the digital world. Therefore, a character-building approach through hypercontent e-modules is an attractive strategy for senior high schools.

Developing effective hypercontent e-modules to strengthen the character of high school students is the general objective of this study. How to develop e-modules that connect with media, video-audio, news sources, and learning resources that are interesting and effective in strengthening the character of high school students.

One of the reasons for developing e-modules in this study is the result of an analysis of student needs, which requires handbooks that are tailored to students' learning styles, which tend to be visual, auditory, or kinesthetic. According to Budi et al. (2021), good learning should accommodate the needs of students according to their learning styles so that students can learn optimally. Therefore, the creation of this e-module also considers the learning styles of students so that all e-module activities can accommodate these three learning styles by connecting the e-module through hypercontent.

Hypercontent E-Module

The development of hypercontent e-modules to strengthen the character of high school students is a much-needed breakthrough to address the limitations of textbooks experienced by schools. By utilizing technology, hypercontent e-modules can present material that is more interesting, interactive, and relevant to the needs of students who are part of the digital generation.

According to Laili et al. (2019), e-modules are electronic learning resources that are structured and interesting, containing subject matter, learning strategies, and evaluations to help students achieve their learning objectives. Meanwhile, according to Prawiradilaga et al. (2017), hypercontent is an approach in learning design that utilizes digital technology to connect learning materials simultaneously. The design of hypercontent modules provides users with the opportunity to study materials from any angle according to their learning needs, without having to start from the beginning. The hypercontent approach directs module design to be enriched by learning resources in cyberspace, such as links to websites, YouTube channels, and others, through URLs, QR codes, and the like. Thus, hypercontent

modules have characteristics that differ from conventional modules, especially in terms of flexibility of access and diversity of learning resources.

According to Prawiradilaga et al. (2017) in previous research, hypercontent is a concept that connects one material to another simultaneously using digital technology. With a real module form with material displayed through digital menus, the module includes links or barcodes that, when clicked, connect users to one material and other supporting materials, or can be easily assumed to be a text that connects to other texts, videos, or other sources (hyper).

Multimedia learning is highly relevant in the development of hypercontent modules for character building. Mayer (2009) compiled several principles that can be used to design effective multimedia learning materials. These principles are very useful in the development of hypercontent modules for character building, including: a) Modality Principle: Verbal material (narrative) should be presented in audio form, while visual material (images, animations) should be presented in visual form. A combination of both will be more effective in improving understanding. b) Syntactic Principle: The order in which material is presented should be logical and coherent. Avoid presenting too much information at once, as this can overload students cognitively. c) Coherence Principle: Material that is not relevant to the learning objectives should be eliminated. Focus on information that is important and relevant. d) Redundancy Principle: Avoid duplicating information in both audio and visual formats simultaneously. This can disrupt the learning process. e) Integration Principle: Combine verbal and visual material synergistically so that they complement and reinforce understanding.

Character

Character education is "any effort that can be made to influence the character of students" (Lickona, 2004, p. 53). It is not just teaching right and wrong, but more than that, it is fostering habits of thinking, feeling, and acting in accordance with values of goodness. The goal is to shape well-rounded individuals who have moral autonomy. Character building is very important in formal education, considering that shaping individuals involves cognitive, psychomotor, and affective aspects. Advanced cognitive development and psychomotor skills must be balanced with high affective skills so that students' cognitive abilities and psychomotor skills can be used and developed for good things that are useful for nature conservation and the welfare of others.

According to Lickona (1991), character education is a conscious effort to instill ethical values in individuals. This concept is in line with the intrinsic motivation theory proposed by Ryan and Deci (2000), which states that individuals will be more motivated to behave in accordance with the values they believe in if those values become part of themselves. In addition, Kohlberg's moral development theory (1984) provides a useful framework for understanding how students develop moral understanding as they age.

Positive values and good life values need to be encouraged and reinforced in students. Internal motivation is a supporting factor in the formation of a person's character, and developing value-based e-modules greatly helps students to build their internal motivation to have values as a form of character building.

Method

Type of Research

This research used a development research method that produces a learning product in the form of a hypercontent e-module. Research and Development (R&D) is a method and strategy for improving various existing problems, especially in the world of education (Asmara 2015). Not only that, the R&D research method is used to create a hypercontent module product by looking at the role of existing problems. The product created in this research is an e-module using the ADDIE development model.

Research Design

The research design for developing value-based hypercontent e-modules to strengthen the character of high school students used the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation.

Table 1. Implementation of the ADDIE Stages

ADDIE Stages	Implementation
Analysis	Needs Analysis Student Analysis Content Analysis (values to be developed)
Design	Designing Hypercontent E-Modules Determination of reinforced values and objectives
Development	Development E-module Hypercontent (test validity)
Implementation	Practicality test
Evaluation	Effectiveness Test

Research Subject

The subjects of this study were 12th-grade students at Pangudi Luhur High School in Surakarta, selected using purposive sampling.

Data Analysis Techniques

Before the e-module was used, a product trial was conducted to obtain data that would then be used to revise the product in the form of a hypercontent e-module. In this study, the trial was conducted on students at Pangudi Luhur Santo Yosef High School in Surakarta. The validity of the product was tested using a validity sheet given to validators. Meanwhile, the effectiveness of the product was tested using an effectiveness instrument in the form of an assessment sheet to determine the learning outcomes of students, which were measured in the cognitive domain. The data were obtained using a Likert scale, as shown in the table below.

Table 2. Scoring with the Likert Scale

Score	Category
1	Strongly Disagree (SD)
2	Disagree (D)
3	Somewhat Agree (SA)
4	Agree (A)
5	Strongly Agree (SA)

The scores obtained were then converted into percentages using the following equation.

$$V = \frac{f}{n} \times 100\%$$

V = value of the validity/effectiveness of the e-module product

f = student achievement score

n = maximum score of students

Meanwhile, the validity/effectiveness category of the product is based on the final score, ranging from 0 to 100, as shown in the table below.

Table 3. E-Module Hypercontent Categories

Interval	Category
$V \leq 20$	Very invalid/ineffective
$20 \leq V \leq 40$	Invalid/ineffective
$40 < V \leq 60$	Less valid/effective
$60 \leq V \leq 80$	Valid/effective
$V > 80$	Highly valid/effective

Thus, value-based hypercontent e-module products are considered valid/effective if the percentage reaches $V > 60\%$.

Findings and Discussion

The development of this value-based hypercontent e-module used the ADDIE model with the stages of Analyze, Design, Develop, Implementation, and Evaluate. The results of each ADDIE stage are as follows.

Analysis Stage

This study used interviews and observations to obtain an initial overview and analyze the needs of the character-building process that had been carried out. Interviews were conducted with teachers and students to analyze the needs and the students. From the results of interviews with teachers, it was found that character building at Pangudi Luhur St. Yosef High School has limited class time, namely 1 JP per week, a lack of physical teaching modules that meet the needs of students, and character-building material that is not contextual. Meanwhile, interviews with students revealed that the teaching modules used in the learning process were insufficient for the number of students, the modules were monotonous, and the material was difficult to understand. Observations showed that the character-building learning process lacked interesting learning resources and was

monotonous. As for material analysis, an analysis of materials in accordance with the independent curriculum and the Foundation's character development curriculum was carried out.

Based on the results of interviews and classroom observations, it is necessary to develop existing modules by linking values to the context of everyday life (contextual), while to compensate for the lack of face-to-face meetings, e-modules with hypercontent can be developed so that students can study independently. while the lack of available modules will be solved by hypercontent e-modules that can be downloaded on each student's mobile phone.

Design Stage:

In this design stage, the development of teaching materials, the design of validity and effectiveness assessments, and the design of the hypercontent e-module display, layout, colors, font choices, and learning stages are carried out to enable students to study the modules independently, honestly, and consciously implement them. The result of this design stage is the development of "Pro-poor" material based on the results of needs analysis and contextual material analysis. It also connects with learning resources that meet the three learning styles of students. As for the assessment sheet, the researcher designed an instrument for material validity and media validity, as well as an effectiveness test sheet consisting of evaluation questions in accordance with the material.

Development Stage

In the developed stage, after conducting development planning in the previous stage, both the design and hyperlinks are connected to learning resources that are contextual to everyday life and current events or phenomena, in order to encourage students to think critically, think creatively, and be knowledgeable so that they can consciously live out positive values to strengthen their character. Therefore, at this stage, validation is carried out by subject matter experts and media experts. The results of the subject matter validation are 94.60% (highly valid), and the results of the media expert validation are 91.67% (highly valid).

Implementation stage

In the Implementation stage, the practicality of the teaching module is tested with teachers and students through a questionnaire after the module has been developed and validated by the validators. The practicality test is conducted with a small group of students, yielding a result of 94%, and a teacher questionnaire, yielding a result of 97%.

Evaluation stage

After going through the previous four stages, data collection was carried out at this stage through knowledge tests administered to students. The product effectiveness test showed that the value-based hypercontent e-module was highly effective, as evidenced by the evaluation test results, with 100% of students completing the test with an average score of 87. It is said to be highly effective because, according to Riduwan (2018), if the effectiveness test results are >80%, it is considered to be in the highly effective category. This is shown in the following table.

Table 4 Effectiveness Test Results

Student	Question Number															Total	Score	Criteria
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	13	87	PASS
2	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	14	93	PASS
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	100	PASS
4	1	0	1	0	1	1	1	1	1	0	1	1	1	1	1	12	80	PASS
5	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	13	87	PASS
6	1	1	1	1	0	0	1	1	1	1	1	1	0	1	1	12	80	PASS
7	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	13	87	PASS
8	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	12	80	PASS
9	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	12	80	PASS
10	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	13	87	PASS
11	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	14	93	PASS
12	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	12	80	PASS
13	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	14	93	PASS
14	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	13	87	PASS
15	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	13	87	PASS
16	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	14	93	PASS
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	100	PASS
18	1	0	1	1	0	0	1	1	1	1	1	1	1	1	1	12	80	PASS
14	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	13	87	PASS
AVERAGE COMPLETION RATE																	100%	
AVERAGE SCORE																	87	

E-Modul Hypercontent Product

Figure 1. Cover

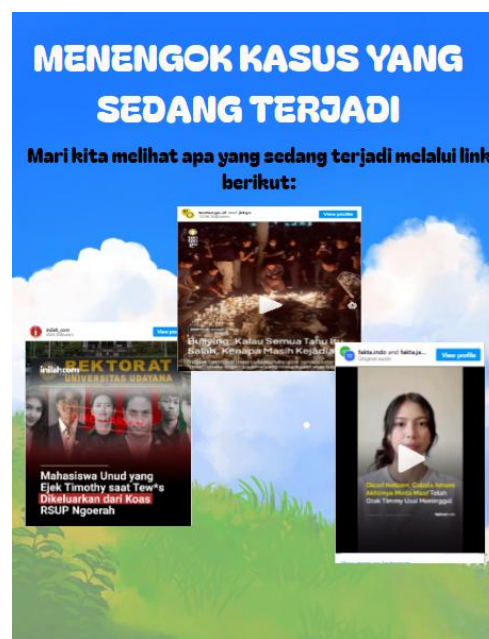


Figure 2. Hyperlink & Contextual



Figure 3. Video Content

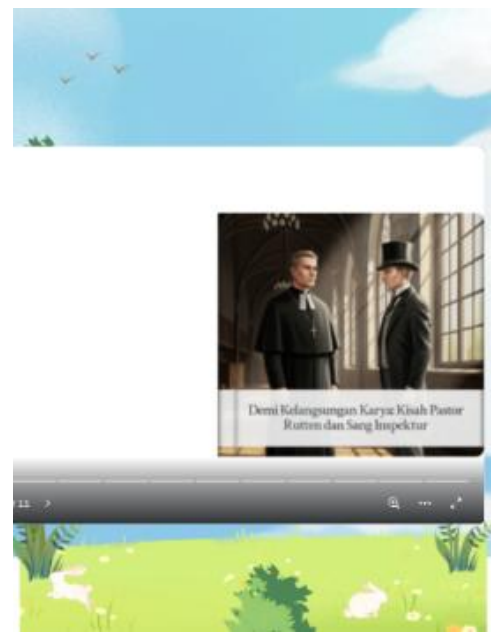


Figure 4. Storyboard

Conclusion

The research results show that the value-based hypercontent e-module has met valid, practical, and effective standards. This value-based hypercontent e-module product meets valid standards, as the assessment from the subject matter experts scored 94.60% (highly valid) and from the media experts scored 91.67% (highly valid). Meanwhile, the e-module meets practicality through the teacher's assessment of 97% and students' assessment of 94%. From the evaluation results, there is 100% effectiveness data, thus showing that the value-based hypercontent e-module product is effective for use.

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SHAPING STUDENTS' ACADEMIC AND CHARACTER TO FACE THE VUCA ERA THROUGH THE INTEGRATION OF ARTIFICIAL INTELLIGENCE-BASED ACCOUNTING LEARNING

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Received: 25 October 2025; Accepted: 10 November 2025

Abstract

In the era of Volatility, Uncertainty, Complexity, and Ambiguity (VUCA), education must swiftly adapt, particularly within the field of accounting. While traditional methods have focused on equipping students with technical knowledge and skills, these can now be performed efficiently by Artificial Intelligence (AI) tools. This shift presents both a challenge and an opportunity to leverage AI not only to enhance students' academic understanding but also to cultivate the essential character needed for the future. This research addresses how an AI-integrated learning model can shape students for the VUCA era. The objective of this mixed-method study is to explore the impact of integrating an AI-based learning model into accounting education. Using a descriptive quantitative approach, data were collected through questionnaires and interviews with 19 Economics Education students, Satya Wacana Christian University, who took a concentration in accounting. These findings suggest that AI-integrated models can improve students' understanding of complex accounting material. Furthermore, these models also aid students in critical thinking, adaptability, and problem-solving. The research shows that an AI-based approach can successfully prepare students to be both academically competent and professionally resilient when implementation includes explicit AI literacy instruction, theory-practice integration through simulations and case studies, and pedagogical frameworks that position AI as a catalyst for higher-order thinking.

Keywords: accounting education, AI-integrated learning, learning model, student character

Introduction

Contemporary education faces challenges where technological advances intersect with increasingly tangible global uncertainty. The VUCA era (Volatility, Uncertainty, Complexity, and Ambiguity) demands fundamental changes in how we prepare students, especially for disciplines such as accounting that traditionally rely on accuracy, standardization, and procedural expertise (Dewi et al., 2025). As artificial intelligence rapidly automates routine tasks and complex calculations, educators face a profound question: What is the purpose of accounting education when machines can perform technical functions with greater speed and accuracy than humans?

However, this question is not a crisis of threat, but rather an extraordinary opportunity. The integration of AI into learning is not just about utilizing



technology; it also means a shift in the learning paradigm from teachers simply teaching students what to do to empowering students with ways of thinking, adapting, and leading in response to rapid changes. Although AI excels at finding information and solving cases (Harry & Sayudin, 2023), it cannot replace human capacity for critical reasoning, ethics, empathy, and creative problem-solving. AI can only do this if users command it according to their wishes. This means that AI is still not smarter than humans; it is only a tool that helps us if we want it to. These competencies, often referred to as 21st-century skills or soft skills, are essential for everyone in an era where change is the only certainty.

Indonesian higher education institutions, especially in the field of accounting, must respond to this transformation proactively. Rather than viewing AI as a threat, it should be accepted as a powerful pedagogical tool that can simultaneously deepen academic understanding and foster essential character traits (Nudin et al., 2023). By appropriately integrating AI-based learning models, educators can create a dynamic learning environment where students engage with complex accounting concepts through interactive experiences while developing the adaptability and innovative thinking skills needed to survive and thrive in a volatile workplace (Choi, 2024; Sabuncu, 2022).

The integration of AI in learning presents extraordinary benefits as well as challenges that teachers must carefully address. On the positive side, AI provides learning experiences tailored to each student's needs, gives immediate feedback, and facilitates access to a vast amount of information (Panjabi et al., 2024). This technology can automatically complete student assignments, allowing students to focus on higher-order thinking skills (Kenwright, 2024). However, these benefits are accompanied by teachers' concerns that students may become dependent on AI, leading to a decline in analytical skills if students become passive consumers of AI-generated answers without filtering, critiquing, and verifying the accuracy of each answer provided (Labadze et al., 2023). The issue of digital divide and inequality arises when not all students have equal access to AI, which has the potential to widen educational disparities. Therefore, the pedagogical challenge is not whether we will use AI or not, but how to integrate it carefully (Williamson, 2024) to maximize its benefits while mitigating its risks.

The World Economic Forum projects that by 2027, AI and automation will transform approximately 23% of jobs globally, with accounting and finance being the most affected sectors. In this context, students must understand not only how to use AI tools but also how to collaborate with them, critically interpret their outputs, and validate them if they are used as a basis for policy (Leitner-Hanetseder et al., 2021). The ability to utilize AI for data analysis is a basic competency that must be possessed, while competencies such as ethical reasoning, good client relations, and strategic thinking will be the distinguishing characteristics between AI and humans (Boddapati et al, 2024). Therefore, integrating AI into accounting education is not merely about keeping up with technological developments, but about preparing students to excel in their field of work, not just being passive consumers of technological disruption, equipping them with the technical fluency and adaptive thinking patterns needed in an AI-supported world (Winokan et al., 2025).

The purpose of this study is to investigate how accounting learning integrated with AI can achieve these dual objectives: improving academic competence and shaping students' character so that they are not only able to survive but also excel

in the VUCA era. By examining the learning experiences of students in the Economics Education program who major in accounting at Satya Wacana Christian University, we can determine whether the AI-based learning that has been implemented so far can shape them into future accountants or teachers who are technically competent, ethical, and ready to face the uncertainties of the future.

Method

This study is a mixed study using a quantitative descriptive approach to reveal whether AI-integrated accounting learning can shape students' academics and character in the VUCA era. A total of 19 students from the Economics Education study program with a concentration in accounting at Satya Wacana Christian University were the respondents in this study. Data were collected using questionnaires and interviews. The questions in the questionnaire referred to the research conducted by Minciu et al (2025). The questions in the questionnaire use two measurement methods, namely the Likert scale for questions 1, 2, 3, 4, 9, 10, 11, and 12, and open-ended questions for questions 5, 6, 7, 8, 13, 14, 15, 16, 17, 18, and 19. This is so that researchers can obtain more detailed and complete information. Below is a list of questions in the questionnaire:

Table 1. List of Questions

Element	Number	Questions
Learning needs in the AI era.	1	How important is it for you to have a strong knowledge of AI.
	2	AI-based tools can help you better understand complex accounting concepts.
	3	Your level of proficiency in using AI for academic purposes.
	4	Accounting education needs to focus more on technology.
	5	The biggest challenge in learning accounting in the digital age.
	6	Courses/topics/materials that are highly suitable for using AI in the learning process.
Hard and soft skills to face the VUCA era.	7	The most important hard skills for future success.
	8	The most important soft skills for future success.
	9	How important is it for the current curriculum to focus on developing soft skillss.
	10	Readiness to enter the workforce with current competencies.
Accounting learning process.	11	The intensity of AI use in learning.
	12	The suitability of current learning methods in line with future needs.
	13	Things that are still not optimal in accounting education today.
	14	Readiness to face the challenges posed by AI.

AI integration for academic character and development.	15	AI-based learning helps in understanding complex accounting concepts.
	16	The use of AI in learning to develop soft skills.
	17	Integrating AI to enhance adaptability.
	18	AI integration encourages students to collaborate and work together.
	19	AI integration makes it easier to apply knowledge and skills.

Quantitative data was processed and analyzed qualitatively using the following data conversion guidelines:

Table 2. Guidelines for Converting Quantitative Data to Qualitative Data

Score Range	Interpretation
4.5 – 5.0	Strong Agreement
3.5 – 4.4	Moderate Agreement
2.5 – 3.4	Uncertain/Mixed
1.5 – 2.4	Disagreement
1.0 – 1.4	Strong Disagreement

Findings and Discussion

Findings

The research results are presented separately, namely the quantitative data analysis and the qualitative data analysis. The following is the data collected in the field.

Table 3. Quantitative Data Analysis

Question Number	Mean	Mode	Distribution
1	4.74	5	Score 5 (15 students), score 4 (3 students), score 3 (1 student)
2	4.11	4	Score 5 (8 students), score 4 (7 students), score 3 (3 student), score 2 (1 student)
3	3.78	3	Score 5 (6 students), score 4 (4 students), score 3 (8 student), score 2 (1 student)
4	4.16	5	Score 5 (8 students), score 4 (7 students), score 3 (4 students)
9	4.53	5	Score 5 (11 students), score 4 (5 students), score 3 (3 students)
10	4.16	5	Score 5 (8 students), score 4 (5 students), score 3 (6 students)
11	4.21	4	Score 5 (7 students), score 4 (9 students), score 3 (3 students)
12	3.89	4 and 3	Score 5 (5 students), score 4 (7 students), score 3 (7 students)

Table 4. Qualitative Data Analysis

Question Number	Result
5	• Limited hands-on application opportunities • Understanding balance sheet and formulas • Complex calculations and data entry processes • Technology dependency • Internet connectivity not universally available
6	• Management accounting • Accounting theory • General accounting topics • Mathematical economics • Communication • Entrepreneurship • All courses
7	• Financial planning • Data analysis • Cybersecurity • AI and learning literacy • Learning management system • Content creator
8	• Critical thinking • Adaptability • Problem solving • Communication • Emotional intelligence • Collaboration
13	• Insufficient practical application • Theory-focused or monotonous • Adaptation difficulties
14	• Not sufficient (42%) • Sufficient (37%)
15	• Strong agreement (53%) • Sometimes (26%) • No, AI is very helpful in finding information but not in understanding (16%)
16	• Strong agreement (58%) • Yes, but not completely (21%) • Depends on individual (22%)
17	• Agreement (68%) • Conditional (21%)
18	• Agreement (63%) • Conditional or depends on method (26%) • Not effective (11%)
19	• Strong agreement (74%) • Depends on individual (16%) • Not effective (11%)

Discussion

Based on the above results, it is clear that knowledge of and expertise in using AI are not optional, but rather a necessity for facing the future. This has a positive impact on the learning environment because students are engaged in AI-integrated learning. Most students feel confident about their ability to enter the workforce, suggesting that they have developed core competencies and strong self-efficacy. Current teaching methods provide students with a sound knowledge foundation (Dehbozorgi et al., 2024; Rahayu, 2025).

Students acknowledged the importance of AI (4.74), and its use intensity was high (4.21); however, they were unsure whether AI can truly enhance learning effectiveness. This uncertainty is reflected in their ability to use AI for academic purposes (3.78). Eight students chose a neutral response, indicating that they know how to use the tool but lack conceptual confidence. This creates a paradox: Students may use AI to quickly find answers, yet this does not result in deep, meaningful, or authentic learning (Montag & Elhai, 2025). This creates a gap between their technical skills in using AI and their pedagogical knowledge. Similar observations have been made, showing that a high level of technology use does not necessarily result in improved learning (Granić, 2022; Almaiah, 2022).

Without explicit instruction and guidance on the effective use of AI, students will not be able to think critically (Gerlich, 2025; Özer et al., 2025). Technical proficiency without pedagogical understanding poses a risk of misuse or overreliance, as Özer et al. (2025) and Obaje (2025) suggest. Teachers must assess AI output to ensure it reflects students' true understanding.

This finding aligns with the responses to Question 15, in which several students stated that AI assists in finding information but does not help with understanding. Using AI solely as an answer-generating tool rather than as a discussion partner can hinder the development of critical thinking skills, which are essential for success in the VUCA era (Hassen, 2025; Wiederhold, 2025).

The responses to Question 9 revealed the various challenges that students face when learning accounting in the digital age. The most common challenge is a lack of practical experience. This explains why some students feel unprepared for the workforce despite having adequate academic knowledge. The gap between classroom learning and real-world practice is a weakness that can be addressed through the strategic integration of AI. Other difficulties relate to technical understanding, such as interpreting a balance sheet, performing data entry, and applying economic mathematics. These responses suggest that, despite their familiarity with AI, students still struggle with accounting material. Students also experience challenges related to rapid change and adaptation. One student expressed concern about the rapid development of education. This reflects VUCA characteristics: students experience uncertainty and volatility not only as future conditions but also as current realities.

In response to the challenges students face, they concluded that financial planning and data analysis are essential hard skills. They acknowledged that an understanding of AI—how it works, its capabilities and limitations, and its applications—would be beneficial if students also possessed these skills (Berikol & Killi, 2021; Sabuncu, 2022). Meanwhile, the soft skills deemed crucial were critical thinking (84%), adaptability (68%), and problem solving (63%). These soft skills are all relevant to the VUCA era (Juniardi et al., 2024). Students understand

that static knowledge alone is insufficient and that they must be lifelong learners who can adapt to new situations and solve problems in diverse and creative ways. These results validate the theoretical framework of this study, which asserts that character development and competency building are essential for students (Fülöp et al., 2025).

The response to question 13 indicated that a limitation of current accounting education is the lack of practical experience. This finding aligns with students' concerns about job readiness. Students realize that conceptual knowledge alone is insufficient for preparing them for the workforce (Tavares et al., 2023). They must be equipped with real-world, complex practices (Zainuddin et al., 2022). A second drawback is that learning remains too theoretical and monotonous. Students desire engaging, interactive, and application-oriented learning experiences. These findings underscore the importance of flexible AI integration to enhance learning quality (Bozkurt et al., 2021).

The presence of AI in accounting education addresses the aforementioned limitations. Question 15 revealed that 53% of students strongly agreed that AI aids in their understanding of complex accounting concepts. One of the students stated that AI helps translate theory into practice, suggesting that these students view AI as a pedagogical tool rather than merely a source of information. However, 26% of students said AI's effectiveness depends on cognitive engagement, and 16% said AI is only useful for searching for information, not for understanding.

Regarding the development of soft skills, 58% of students strongly agreed that AI can foster critical, creative, and analytical thinking. One of the students stated that AI shifts the focus from calculations to analysis. However, another student expressed a different view, stating that there is a tendency to use AI to cheat. These responses demonstrate that, while AI can stimulate creative thinking, it can also undermine critical and analytical thinking if used unwisely (Gerlich, 2025; Obaje, 2025). This perspective aligns with learning best practices, which emphasize using AI to support learning rather than replacing cognitive work. The diverse responses to this question indicate that students have different understandings of AI's role and impact on learning. Some view AI as a cognitive tool that develops thinking skills, while others see it as a source of information for thinking, not as an extension of themselves. These differing views underscore the need for an explicit pedagogical framework for the role of AI in learning (Weng et al., 2023; Yang et al., 2024). Questions 17 and 18 examine the impact of AI on adaptability, collaboration, and cooperation. Over 60% of students agreed that integrated AI can enhance these capacities. Therefore, one could argue that AI integration equips students with the essential skills needed in the VUCA era.

Conclusion

Overall, these findings reveal that students have mastered the use of AI, but they also feel uncertain about the role of AI in their learning. They recognize the importance of AI, use it frequently, and are aware of its benefits and risks. However, they are not so sure about its effectiveness in learning. The challenges faced by students, lack of practical experience, complexity of accounting concepts, and rapid changes are challenges that can be overcome by AI if applied appropriately. The key skills students need in the VUCA era are critical thinking, adaptability, and problem-solving, complemented by technical skills in financial planning and data

analysis, which are competencies they feel they lack in AI-integrated learning. However, this development requires more than just tools; it requires structured learning experiences that explicitly teach students to collaborate with AI, not just use it. The existence of pedagogical gaps, such as too much theory and too little practice, as well as monotonous delivery methods, creates both urgency and opportunity for transformation. The integration of AI will have a very positive impact on students' academics and character only if teachers redesign learning activities to involve student activities and learning experiences.

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A SYSTEMATIC LITERATURE REVIEW OF STUDENTS' PROBLEMS IN SOLVING SYSTEMS OF LINEAR INEQUALITIES IN TWO VARIABLES

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Received: 30 September 2025; Accepted: 12 November 2025

Abstract

This study aims to analyze the problems students encounter in solving systems of linear inequalities in two variables, including difficulties, errors, misconceptions, and learning obstacles. The method used in this research is a Systematic Literature Review (SLR) on 13 articles from national journals, international journals, and international seminar proceedings published between 2015 and 2025, obtained through Google Scholar. The findings identified four main categories of student problems: (1) conceptual problems, such as understanding inequality signs; (2) procedural problems, related to steps and calculations; (3) representational problems, including difficulties in drawing graphs and determining solution regions; and (4) modelling problems, namely the inability to accurately translate the problems into mathematical models. These findings suggest the need for more targeted instructional strategies to help students overcome and prevent various learning problems in solving systems of linear inequalities in two variables.

Keywords: misconceptions, mathematics error, student learning difficulties, systematic literature review, two-variable linear inequalities

Introduction

Mathematics serves not only as a means of understanding abstract concepts but also as a fundamental tool for analyzing and solving real-world problems. Through the learning of mathematics, individuals develop critical reasoning and logical thinking skills that are essential for problem-solving across various domains. One important aspect of mathematics that is widely used in everyday life is mathematical modelling (Palupi et al., 2022). Within this domain, inequalities play a crucial role due to their practicality and significance in representing constraints and relationships in diverse mathematical models (Arseven, 2015).

The understanding of inequalities is foundational for students, as this concept is interrelated with other mathematical topics and underpins more advanced ideas such as linear programming, optimization, and higher-level algebra (Moon, 2019). However, despite their importance, inequalities still receive limited attention in the curriculum. They are often taught together with equations, which makes them appear more like a complement or an extension of equations rather than a separate conceptual domain (Bazzini et al., 2004). For example, in the Indonesian high school curriculum, systems of linear inequalities in two variables are placed alongside systems of linear equations in two variables (Kemdikbudristek, 2022).



This way of presenting the material often leads to students' difficulties and overlooks the distinct characteristics of inequalities when dealing with them (Blanco & Garrote, 2007).

The concept of inequality has been applied by mathematicians for a long time, particularly in geometry, even before the symbols were formally introduced by Thomas Harriot in the 17th century (Muhammad & Jupri, 2023). An inequality is defined as a number sentence that contains $>$, $<$, $\geq$, or $\leq$ as its verb (Bittinger, 2019). A system of linear inequalities refers to two or more linear inequalities with the same variables that are considered simultaneously (Redden, 1985). For example,

$$\begin{cases} y > x - 4 \\ y \leq 4x + 4 \end{cases}$$

represents a system of linear inequalities containing the variables x and y .

Unlike equations, inequalities can have a solution set that has an infinite number of solutions, a set that has a discrete number of solutions, or no solutions at all (Gloag et al., 2012). An ordered pair (x, y) is a solution of a system of linear inequalities if it satisfies each of the inequalities in the system. Because the solution set often contains infinitely many points, it is usually represented graphically in two dimensions. The overlapping region of the graphs of two inequalities shows all the points that satisfy both simultaneously (Major & Park, n.d.). However, the procedure for graphing a system of inequalities is quite similar to that of graphing a system of equations, even though the underlying concepts are fundamentally different. Research has shown that many students experience difficulties in making this transition, which often results in problems when solving the system of linear inequalities in two variables, such as errors, difficulties, misconceptions, and learning obstacles (Taqiyuddin et al., 2017). Hence, it is necessary to investigate these difficulties in order to inform more effective teaching strategies and support students' understanding.

Numerous studies have investigated students' problems in solving systems of inequalities, yet these findings are often discussed separately and not examined as a whole. As a result, there is still a lack of comprehensive understanding of the range and nature of students' difficulties in this topic. To address this gap, this study employs a Systematic Literature Review (SLR) of research published between 2015-2025 in national and international journals as well as conference proceedings. By synthesizing the findings, it aims to identify and categorize students' difficulties in solving systems of linear inequalities in two variables, and to enrich the existing insights that may inform more effective instructional strategies.

Method

The method used in this research is a Systematic Literature Review (SLR) that identifies, studies, evaluates, and interprets every research conducted on a particular topic (Naufal & Juandi, 2024; Triandini et al., 2019). Systematic Literature Review (SLR) is used to provide a transparent and logical approach to synthesizing the literature (Bearman et al., 2012). This method consists of five steps: 1) constructing the research questions, 2) obtaining the articles, 3) assessing articles, 4) summarizing, and 5) interpreting findings (Khan et al., 2003).

This review seeks to answer the following questions: 1) What problems do students encounter when solving systems of linear inequalities in two variables, such as difficulties, errors, and learning obstacles? 2) What factors contribute to these problems? The journal articles compiled through Google Scholar using the following keywords: “students’ difficulties” AND “linear inequalities” OR “students’ errors” AND “linear inequalities” OR “students’ misconceptions” AND “linear inequalities” OR “learning obstacles” AND “linear inequalities. Studies were included if they satisfied these criteria: 1) relevant scientific journal from national and international or international conferences on the topic of linear inequalities in two variables; 2) published in 2015-2025. After removing duplicates, articles were identified and processed by grouping, analyzing, and concluding data.

Findings and Discussion

The selection of articles was determined by applying inclusion criteria. A total of 13 articles were selected for in-depth analysis. The eligible articles are presented in Table 1.

Table 1. List of Selected Articles

Title	Author(s)	Journal	Year
Analisis Kesalahan Konsep Siswa pada Materi Sistem Pertidaksamaan Linear Dua Variabel	Yanti Nurhayati, Nani Ratnaningsih	PRIMATIKA	2023
Analisis Kesalahan Siswa dalam Menyelesaikan Soal Sistem Pertidaksamaan Dua Variabel Berdasarkan Newman	Resi Erni	Prinsip	2021
Analisis Kesulitan Siswa dalam Menyelesaikan Soal Sistem Pertidaksamaan Linear Dua Variabel Menggunakan Teori Pemahaman Skemp	Desy Anggraini, Dian Devita Yohanie, And Aan Nurfahrudianto	Jurnal Ilmiah Pendidikan Citra Bakti	2024
Kesalahan Mahasiswa dalam Menggambar Grafik Fungsi Pertidaksamaan Linear	Ratnah Kurniati MA, Sigit Sugiarto	Sora Journal of Mathematics Education	2023
Analisis Kesalahan Skill dalam Menyelesaikan Soal Sistem Pertidaksamaan Linear Dua Variabel pada Studi Kasus Siswa Kelas X MIA 6 SMA Negeri 4 Kota Ternate	Sahjuan Umasangaji, Yahya Hairun, Ahmad Afandi	Saintifik@ Jurnal Pendidikan Mipa	2020
Analisis Kesalahan Siswa dalam Menyelesaikan Soal Hots Materi Sistem Pertidaksamaan Linear Dua Variabel: Perspektif Teori Kastolan	Budi Halomoan Siregar, Sinta Marintan Sinaga, Putri Andini, Nurul Masita, Nia Fadilla, Gustia Louisa Nainggolan, Elva Waniza, Dea Athalia Siregar	Jagomipa	2024
Exploring Potential: Analysis of Students' Mathematical Problem-Solving Ability on	Febri Loska, Ayuni, Nailu Ainirohmah	International Journal Applied Learning and	2024

System of Linear Inequalities in Two Variables (SLITV) Material		Research in Algebra	
Student Errors in Solving Story Problems on Systems of Linear Inequalities Based on Newman Error Analysis (NEA)	Astrino Purmanna, Sigit Raharjo, Muhamad Arie Firmansyah, Rika Sukmawati, Syahrani Aswar, Revita Tri Cahya Ningsih	Mathema Journal	2024
Kesalahan dalam Menyelesaikan Soal Koneksi Matematis Materi Sistem Pertidaksamaan Linear Dua Variabel	Rostika Nurlaela Nova Maya Sofa, Sufyani Prabawanto	JPMI	2023
Analisis Kemampuan Matematis Siswa SMA dalam Menyelesaikan Soal Cerita pada Materi Sistem Pertidaksamaan Linear Dua Variabel	Ernawati Jais, Suwarni La Usa, Nur Paisa	Jurnal Akademik Pendidikan Matematika	2023
Learning Obstacles of High School Students in Computational Thinking on Two-Variable Linear Inequality System	Aswin, Al Jupri, Sufyani Prabawanto	Jurnal Gantang	2025
Kesulitan Berpikir Reflektif Matematis Siswa dalam Menyelesaikan Soal Sistem Pertidaksamaan Linear Dua Variabel Ditinjau dari Gaya Belajar	Meidayanti Buyung, Nurma Angkotasan, Dan Ariyanti Jalal	Jurnal Pendidikan Guru Matematika	2023
Variation of Vocational Students' Difficulties in Solving System Linear Inequality Problem Based on Polya's Theory	Ika Wulan Junianti, Subanji, Hery Susanto	MaPan: Jurnal Matematika dan Pembelajaran	2025

As shown in Table 1, the earliest eligible paper was published in 2020, although the search initially covered publications from 2015 onwards. This suggests that scholarly interest in the topic of systems of linear inequalities in two variables has only recently emerged. All of the studies included were conducted in Indonesia, even though published in international journals. Furthermore, this review encompasses all relevant research addressing the problems or barriers encountered by students in solving such systems, which can be categorized into abilities, errors, difficulties, and learning obstacles as presented in Table 2.

Table 2. Data Based on Problems

Year	Category			
	Ability	Error	Difficulty	Learning Obstacles
2025			1	1
2024	1	2	1	
2023	1	3	1	
2021		1		
2020		1		
Total	2	7	3	1

Based on Table 2, from 2020 to 2025, the majority of studies focused on identifying students' errors in solving systems of linear inequalities in two variables. It is evident that the focus on errors has remained prominent up to 2024, indicating that students continue to make persistent and observable mistakes in this topic despite ongoing instructional efforts. In contrast, research on students' abilities, difficulties, and learning obstacles has been relatively balanced in number, suggesting that these areas still not yet received the same level of attention as error analysis.

Students' Ability, Errors, and Difficulties

In the ability category, both studies report similar findings, emphasizing that students' mathematical abilities in solving systems of linear inequalities in two variables remain lacking (Jais et al., 2023; Loska et al., 2024). While students are generally able to comprehend problem statements, they often struggle in more advanced stages that require higher-order reasoning, such as representing graphics and verifying the solution. Particularly in problem-solving tasks, their competency in selecting and developing solutions is notably low. Both studies also discussed, and point to possible factors underlying these weaknesses may be partly attributable to instruction that highlights routine procedures, limiting students' opportunities to explore and develop flexible problem-solving skills.

Seven studies included and categorized as error did not rely on a single analytic framework to identify the frequent mistakes. Several studies employed Newman's Error Analysis, Kastolan's, and researcher-developed categories. The studies focusing on errors provided more detailed evidence of specific mistakes students made during the solving process.

Across these studies, the errors were identified into three types: conceptual, procedural, and technical. Conceptual errors included misinterpreting inequality signs, misunderstanding the meaning of (x,y) , and failing to visualize the region of solution in the Cartesian plane. Procedural errors typically involve selecting or sequencing inappropriate solution steps, such as graphing an equality without converting it first to its linear equation. Technical errors included arithmetic and substitution mistakes. Some studies that used Newman's Error Analysis further stated that the most frequent mistakes occurred at the comprehension, transformation, and process skill stages. These findings collectively indicate that conceptual weaknesses and a lack of strategic procedural competence underlie many of the recurrent errors in this topic (Erni, 2021; Kurniati, 2024; Nurhayati &

Ratnaningsih, 2023; Purmanna & Raharjo, 2024; Siregar et al., 2024; Sofa & Prabawanto, 2023; Umasangaji et al., 2021)

Studies' findings show that students experience a variety of difficulties in solving systems of linear inequalities in two variables (Anggraini et al., 2024; Buyung et al., 2023; Junianti et al., 2025). Similar to error, difficulty is categorized into conceptual, procedural, and reflective-evaluative. Conceptually, students find it difficult to state or reconnect concepts. Procedural difficulty, such as applying algorithms, drawing graphs, and choosing solution regions. Reflective- evaluative, including checking and justifying the correctness of the answer. Students with low ability tend to struggle in all categories, while students in medium-high ability demonstrate stronger relational understanding but still have a hard time in word problems and abstract representations. The most consistent difficulties across studies are found in the evaluation/justification of the answers.

The three categories above are actually interrelated and not separated; this can be seen in how the findings reveal corresponding results. While ability may reveal lacking parts where frequent mistakes occur, repeated error is the indicator of difficulty (Aljura et al., 2025). Comprehension or interpretation errors, for example, usually occur alongside conceptual difficulties, while errors in procedures are associated with difficulties in strategies or algorithms.

The synthesis of findings across ability, error, and difficulty categories reveals a consistent pattern in problems faced by students when solving this topic. Students faced problems in selecting and developing effective solution strategies. This persistent gap between conceptual understanding and flexible procedural as well as strategic competence reflects a common challenge in mathematics learning (Rittle-Johnson & Schneider, 2014). This suggests that the surface-level problems are the manifestations of more fundamental learning obstacles, which will be further examined in the following section.

Learning Obstacles

In contrast to the previous categories, there is only one relevant article to the topic of learning obstacles, published in 2025. This insinuates that the studies regarding learning obstacles still not yet received the same attention, especially in the topic of systems of linear inequalities in two variables. The findings of the research classified the obstacles in students' computational thinking into three categories according to Brousseau (2002), which are ontogenical, epistemological, and didactical (Aswin et al., 2025).

Ontogenetic obstacles identified are that students struggled to build mathematical models due to misinterpreting information and a lack of understanding of how to make mathematical models, meaning this obstacle was caused by insufficient prerequisite knowledge, such as determining and graphing coordinate points. Epistemological obstacles identified, such as difficulties in pattern recognition, abstraction, and generalization when solving unfamiliar problems, originate from limited practice and exposure to context. Didactical obstacles such as misunderstood or using the wrong inequality symbols sourced from an understated definition or instruction. The paper emphasizes that both student readiness and instructional design, including textbook and problem variation, significantly contribute to these obstacles.

By tracing students' observable abilities, errors, and difficulties, we can identify stable and systematic learning obstacles (Blanco & Garrote, 2007). Understanding this layered relationship is essential for designing instruction that not only corrects mistakes but also disconnects the underlying barriers to learning. Addressing these obstacles requires both conceptual reinforcement and instructional understanding.

Conclusion

This systematic literature review synthesized findings from 12 studies on students' challenges in solving systems of linear inequalities in two variables. The review identified four recurring domains of problems: (1) conceptual problems, such as misunderstanding inequality signs and the meaning of ordered pairs; (2) procedural problems, involving inappropriate or incomplete solution steps and calculation slips; (3) representational problems, including difficulties in graphing and identifying feasible regions; and (4) modelling problems, namely struggles in translating real-world or word problems into mathematical models.

The synthesis further revealed that these surface-level problems—reflected in students' limited abilities, recurrent errors, and persistent difficulties—are rooted in deeper learning obstacles, including gaps in prerequisite knowledge, limited opportunities for conceptual exploration, and instructional practices that emphasize procedural routines over strategic problem-solving. Such obstacles hinder students from integrating conceptual understanding with flexible procedural and strategic competence.

These findings highlight the need for targeted instructional approaches that not only correct procedural mistakes but also strengthen students' conceptual foundations, enhance their representational skills, and promote strategic competence. Future research should expand the investigation of learning obstacles across diverse contexts and explore instructional designs that effectively address both the cognitive and instructional sources of these persistent challenges.

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**THE IMPLEMENTATION OF SCAFFOLDING TECHNIQUE
TO ENHANCE STUDENTS' SPEAKING SKILLS IN INTENSIVE
ENGLISH CLASS AT DIV ANAESTHESIOLOGY
UNIVERSITAS MUHAMMADIYAH BANJARMASIN**

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Received: 16 October 2025; Accepted: 18 November 2025

Abstract

This study explores the implementation of scaffolding techniques and their role in enhancing students' speaking skills in the Intensive English Class of the DIV Anaesthesiology Study Program at Universitas Muhammadiyah Banjarmasin. Employing a qualitative descriptive design, the research involved one lecturer and 37 students selected through purposive sampling. Data were collected through classroom observation, interviews, and analysis of students' speaking performance in the middle and final tests. The findings indicate that the lecturer applied scaffolding strategies such as modelling, prompting, questioning, providing cues, and giving feedback to support students' oral production. The comparison between test results demonstrated noticeable improvements in pronunciation, vocabulary, fluency, grammar, and confidence. Both lecturer and student perspectives confirmed that scaffolding reduced speaking anxiety, fostered motivation, and guided learners within their Zone of Proximal Development. The study concludes that systematic integration of scaffolding can be an effective pedagogical approach to improve speaking competence, particularly in non-English majors. These results highlight the potential of scaffolding to bridge learning gaps and enhance communicative ability in English for Specific Purposes contexts.

Keywords: Intensive English Class, qualitative descriptive research, scaffolding, speaking skills, Zone of Proximal Development

Introduction

English is an international language that plays a central role in global communication, education, and professional development. According to Virgana & Lapasau (2019), English as lingua franca plays a major role in cross-cultural communication, education, and the workforce. Likewise, Tika & Dewi (2022) argue that acquiring English as a foreign language has become a vital skill for those aiming to communicate verbally with people worldwide, particularly since a large portion of the global population understands and uses this language. Accordingly, Rajendran and Yunus (2021) concur that the four language skills in English, speaking is often regarded as the most difficult for learners to master—a challenge that becomes even greater given the crucial importance of this skill. Among the four language skills are listening, speaking, reading, and writing. Similarly, Efrizah et al. (2024) believe that frequent challenges include weak pronunciation, limited



fluency, restricted vocabulary, and anxiety that impedes effective English communication.

At the Universitas Muhammadiyah Banjarmasin, there is an Intensive English Class program for first and second semester university students, particularly those in professional programs such as the DIV anaesthesiology at *Fakultas Keperawatan dan Ilmu Kesehatan* Universitas Muhammadiyah Banjarmasin. The most important skill in the Intensive English Class is speaking. Speaking English is not only important for academic success but also for preparing them to meet the demands of their future careers in the medical field. Enhancing speaking abilities can be difficult for undergraduates with limited vocabulary and grammatical accuracy. While they may possess fundamental grammar knowledge, they often lack sufficient opportunities to practice and refine their speaking skills. Scaffolded interactions help build students' confidence in using English orally. Teachers are thus advised to implement scaffolding strategies that are well-suited to the needs of university students. The use of scaffolding strategies can support learners in developing their speaking abilities, resulting in progress in the target language. Such strategies encourage interactive learning activities and refine learners' oral output, thereby stimulating greater participation in the learning process.

Speaking Skill

Speaking is often considered the most challenging yet essential skill to master. As Brown (2001) states, speaking represents a productive language skill in which learners must produce speech and express their ideas immediately. Similarly, Harmer (2007) found that the capacity to speak in a foreign language is widely regarded as the key measure of language learning success, given that learners are assessed through their oral communicative competence. In addition, Darmuki (2019) said that through speaking, individuals are expected to communicate, express ideas and messages, engage in interaction, and exchange information so that others can understand them. Furthermore, Sabnani (2024) believes that effective speaking enables language learners to interact smoothly in both academic and social contexts, highlighting that speaking proficiency is essential not only for communication but also as a means of supporting learning. According to Thornbury (2005), to speak effectively, learners must achieve fluency, accuracy, and appropriacy, but balancing all three is often a challenge. Fluency in speaking holds great importance since it helps individuals nurture social bonds and carry out transactional communication by transferring information. According to Dionar and Adnan (2018) demonstrate that speaking serves as a means of expressing sounds or words to convey, explain, and communicate emotions, ideas, and thoughts. It is through speaking that learners are able to express their thoughts, share ideas, and engage in interactive communication. Peterson (2021) illustrates that the speaker should be capable of conveying information to others, which implies that effective and coherent communication requires the speaker to have a clear understanding of how to express ideas so that listeners can easily and accurately grasp the intended message.

Medical professionals are often required to read and discuss international medical journals, attend conferences, and sometimes collaborate with foreign colleagues or interact with patients from diverse backgrounds. Therefore, students of anaesthesiology must develop not only medical competence but also

communicative competence in English. Niazi (2012) argues that for medical students, English is essential both for understanding their field of study and for advancing their professional aspirations. However, a lot of students continue to find it difficult to speak English with confidence and precision. Their struggles include limited vocabulary, frequent grammatical mistakes, hesitation, and a lack of fluency. According to Apriani et al. (2019), attaining fluency in speaking, reading, and writing in English necessitates a strong foundation in the essential aspects of the language. In addition, Iksan et al. (2021) state that speaking is a fundamental skill that fosters social cohesion, builds relationships, and helps address communal challenges. It is highly valued by students for its relevance in real-life contexts, as it enables the expression of ideas and emotions. Psychological factors such as fear of errors and speaking anxiety further obstruct their performance, particularly in intensive English classes that prioritise active language use.

Scaffolding Strategies

To overcome these challenges, teachers must provide effective support that encourages students to actively participate in speaking activities. One widely recognised approach is the scaffolding technique, rooted in Vygotsky's (1978) sociocultural theory and the concept of the Zone of Proximal Development (ZPD). Vygotsky argues that learning occurs most effectively when students are guided to perform tasks slightly beyond their independent ability, supported by teachers or more capable peers. Building on this theory, Wood et al. (1976) first introduced the term "scaffolding" to describe the process of providing temporary assistance that enables learners to accomplish tasks they could not manage alone. This supportive approach, as outlined by Hammond and Gibbons (2005) it includes six forms of interactional scaffolding designed to help students move beyond their zone of proximal development (ZPD): 1) Activating prior knowledge, where teachers connect new material to learners' existing understanding to build a solid conceptual foundation; 2) Highlighting key ideas, which involves summarizing important points to ensure comprehension of essential content; 3) Modelling, in which teachers demonstrate their thinking or ideas for students to observe and adopt; 4) Refining student responses, where teachers help learners improve the clarity and appropriateness of their language or ideas; 5) Using cues or gestures, to prompt and guide students toward expected answers or behaviours; and 6) Encouraging expression, by providing multiple chances for students to articulate and reflect on their thoughts. Similarly, Walqui (2006) further stresses that scaffolding is not about simplifying tasks but rather about creating learning opportunities that enable students to develop higher levels of competence. She identifies strategies such as modelling, bridging, contextualization, questioning, and feedback as essential scaffolding moves. Scaffolding talk enables students to express intended ideas, allowing teachers to proceed to the main discussion and achieve instructional goals, including mastery of the target language.

In the context of language learning, scaffolding is seen as a powerful strategy to develop learners' communicative competence. Gibbons (2002) explains that scaffolding in second language classrooms involves planned support that allows learners to engage in challenging tasks while gradually gaining independence. Furthermore, Anggadewi (2017) suggests that a productive strategy involves designing learning materials that cater to students' specific needs, which helps

boost their confidence and motivation to learn. Scaffolding is particularly relevant for intensive English classes because it allows students to practice speaking in a supportive and interactive environment. Taber (2017) contends that scaffolding goes beyond merely organising learning activities; it also involves ensuring that each task aligns with the learning objectives that students may find difficult to accomplish independently. In addition, Spadafora and Downes (2020) highlight that the role of argumentation skills in scaffolding is crucial, as they promote critical thinking and encourage students to examine topics from multiple perspectives. It helps reduce anxiety, encourages participation, and builds students' confidence step by step. Anita (2019) states that this scaffolding approach provides students with opportunities to actively participate in classroom activities. Thus, Harraqi (2017) believes that scaffolding also helps students gain a clearer understanding of complex concepts. Moreover, Heron and Webster (2019) show that scaffolding is implemented to assess students' comprehension, establish academic benchmarks, clarify the overall context of the teaching and learning process, and direct students' focus toward previous and upcoming topics, lessons, and assessments. Similarly, Pashayev et al. (2024) say that scaffolded learning strategies enhance students' engagement and retention of English language skills more effectively than traditional approaches, while also accommodating diverse learning needs and promoting motivation. Scaffolding creates a more comfortable classroom atmosphere and encourages frequent discussions, allowing students to engage in guided interactions that enhance their confidence and performance in EFL speaking while increasing their motivational engagement. For anaesthesiology students, scaffolding can also be tailored to their academic and professional needs, such as learning to explain medical procedures, asking questions in clinical discussions, or engaging in role-play simulations related to healthcare contexts.

Although scaffolding has been widely recognised as an effective teaching strategy, its application in specialised university programs, especially in the health sciences, is still under-researched. This study, therefore, seeks to investigate the implementation of scaffolding techniques in the Intensive English Class of the DIV Anaesthesiology Program at Universitas Muhammadiyah Banjarmasin and to explore how it contributes to the improvement of students' speaking skills. Based on the background above, students in the DIV anaesthesiology program still encounter difficulties in speaking English, both in terms of linguistic accuracy and self-confidence. While scaffolding techniques are believed to support students in overcoming these challenges, there is limited research examining how scaffolding is implemented in specialised university programs such as anaesthesiology. This research seeks to address this gap.

Method

This research employed a qualitative descriptive research design to investigate the implementation of scaffolding techniques and their role in enhancing students' speaking skills in an Intensive English Class at DIV Anaesthesiology Universitas Muhammadiyah Banjarmasin. Qualitative descriptive design was chosen because it provides a straightforward and detailed account of teaching and learning practices (Sandelowski, 2000). The focus of the study is twofold: (1) to describe how scaffolding techniques are implemented by the lecturer, and (2) to

analyse how students' speaking performance improves, measured through middle and final test results.

Research Setting and Participants

The research was conducted in the Intensive English Class at the DIV Anaesthesiology Study Program, Universitas Muhammadiyah Banjarmasin, during the second semester 2024/2025 academic year. Participants included: One English lecturer, who is teaching an intensive English class for delivering speaking lessons. 37 students enrolled in the class participated in both the middle and final tests. Sampling was done using purposive sampling (Creswell, 2012), ensuring participants had direct experience with scaffolding and speaking activities.

Data Collection Techniques

The data were collected using three main techniques: Classroom Observation, Interviews, and Speaking Tests (Middle Test and Final Test). The researcher observed the lecturer's implementation of scaffolding strategies during speaking lessons. An observation checklist was used, focusing on strategies such as modelling, prompting, questioning, providing cues, and feedback (Wood, Bruner, & Ross, 1976; Walqui, 2006). Field notes were also taken. Interviews were conducted with the selected students. The lecturer's observations focused on lesson planning, scaffolding strategies, and challenges in implementation. Student interviews explored their experiences of scaffolding, difficulties in speaking, and perceptions of improvement. Students' speaking performance was assessed through the middle test and final test, both designed to evaluate speaking competence. After the middle test, the researcher analysed the scores to identify students' weaknesses. Based on this analysis, scaffolding strategies were applied systematically to support students in areas such as pronunciation, vocabulary, fluency, and confidence. The final test scores were then compared with the middle test scores to examine the extent of students' improvement.

Findings and Discussion

In general, the lecturer employed this scaffolding technique in the middle of the semester, specifically after conducting the mid-semester test on speaking skills. However, the teacher found that the students were still unable to reach the target of the speaking skill assessment. Therefore, the teacher utilised the scaffolding strategy to enhance their speaking abilities. In addition to helping learners enhance their speaking skills, scaffolding learning strategies also fosters creativity, as certain objectives and understandings are linked to the growth of learners' self-concept (Gonulal & Loewen, 2018). Permadi (2019) claimed that scaffolding is a crucial instructional strategy that learners need. Similarly, Naibaho (2019) demonstrated that implementing scaffolding elicits positive responses to learning activities and enhances student motivation, thereby positively influencing the development of speaking skills. Hance, Abedi (2022) concluded that scaffolding contributed to notable enhancements in students' fluency, coherence, and lexical resource. In classroom observation, the researcher concentrated on scaffolding strategies for teaching speaking at Universitas Muhammadiyah Banjarmasin. Assisting English learners' performance in the intensive English class. The implementation of scaffolding in English is very helpful for students in achieving assessment targets.

Furthermore, DIV Anaesthesiology students can significantly improve their English-speaking skills. This improvement is evident in the final test results, whereas in the middle test, only a few students had reached the assessment targets. After receiving scaffolding treatment from the lecturer, an enhancement in their English proficiency was observed. Oliveira et al. (2021) argue that Teachers played a crucial role in the classroom, serving as key figures who determined and structured how effective the learning process would be. Similarly, with (Bukit, 2020), educators can adapt their instructional approaches to accommodate the learning needs of their students. For professional worker, English is important for supporting their future careers. Sabnani (2024) believes that being able to speak effectively enables language learners to engage in both academic and social interactions, highlighting that speaking proficiency is essential not only for communication but also as a means of facilitating learning. Learning English as a foreign language has become a vital skill for those aiming to engage in spoken communication worldwide, as a significant portion of the global population understands and uses the language (Tika & Dewi, 2022).

Lecture Implementation Scaffolding Techniques

The lecture delivery was incremental and passed through three key stages: modelling, scaffolded practice, and independent performance. During the subsequent stages, teachers support learning by guiding students through various scaffolding techniques such as instruction, modelling, questioning, prompting, and providing feedback (Xu et al., 2021). All three stages aimed to prepare students to move from teacher-supported learning to being able to independently manipulate language.

Firstly, during the modelling phase, the instructor presented new linguistic forms and medical vocabulary by providing demonstrations and examples. Scaffolding strategies aimed at developing metacognition involve offering examples of tasks and discussing them (e.g., through modelling), as well as proposing meta-strategies to assist students in completing those tasks (Grossman 2015). For example, the lecturer illustrated the use of polite expressions in patient interactions and demonstrated how to summarise brief medical texts in English. This may involve modelling and offering strategies for completing concrete tasks (e.g., producing physical objects) as well as demonstrating how to engage in effective and respectful discussions (Grossman 2015). This phase offered students concrete reference models and helped lessen their anxiety when encountering unfamiliar terms. Modelling involves guided walkthroughs where the teacher first prompts students to define key terms and then demonstrates an appropriate response (Mahan 2022).

Secondly, in the guided practice phase, students participated in interactive classroom activities to practice every meeting under the lecturer's close supervision. Boonkit (2010) demonstrated that students need structured practice to achieve fluency, highlighting that without appropriate guidance, they tend to rely on memorised phrases instead of producing spontaneous speech. Kulsoom et al. (2021) also reported notable progress in the influence of the scaffolding strategy on students' English-speaking fluency. The lecture utilised questioning, prompting, and corrective feedback as key scaffolding techniques. Learners took part in pair work, role-playing, and speech in front of class. Throughout this stage, the lecturer

observed students' performance and tailored the level of assistance according to their individual needs, ensuring active participation and comprehension of the lesson material.

Finally, during the independent performance phase, the lecturer gradually lessened support, enabling students to complete tasks with minimal guidance. The research of Sari and Rozimela (2021) has acknowledged that independence in learning is provided to students through scaffolding in speaking classes. In addition, Spadafora and Downes (2020) highlight that the significance of argumentation skills within scaffolding lies in their ability to promote critical thinking and help students examine topics from multiple perspectives. These tasks included delivering medical case presentations, playing a role similar to that of a hospital between patients and nurses, and participating in group discussions. Through the gradual withdrawal of assistance, the lecture encouraged students to use their language skills independently and confidently in both academic and clinical contexts.

The results suggest that the scaffolding approach in the Intensive English Class was applied as a step-by-step instructional method after the middle test in speaking skills, progressing from strong teacher guidance to learner independence. This approach corresponds with Vygotsky's (1978) theory of the Zone of Proximal Development (ZPD), which posits that learners develop greater competence through guided interaction before performing tasks independently. The lecturer's application of modelling, feedback, and the gradual transfer of responsibility is consistent with the findings of Wood et al. (1976) and Hammond and Gibbons (2005), who highlight scaffolding as a strategy to bridge the gap between learners' current skills and their potential growth.

In summary, the scaffolding strategy in the Intensive English Class at the DIV Anaesthesiology program was successfully applied through a structured series of scaffolding instructional stages to improve speaking skills. This method not only improved students' language proficiency but also strengthened their confidence and independence in using English for both medical and academic communication.

Scaffolding Technique Improves Students' Speaking Skills

In interviews with students participating in the intensive English class and the analysis of documents from the midterm and final tests, the scaffolding technique implemented by the lecturer played a significant role in improving speaking skills and achieving the assessment targets at the end of the semester. Frequent challenges include weaknesses in pronunciation, insufficient fluency, limited vocabulary, and anxiety that obstructs effective communication in English (Efriyah et al., 2024). Scaffolding serves to assess students' comprehension, establish academic standards, provide a broader perspective of the teaching and learning process, and draw students' attention to previous and forthcoming topics, lessons, and assessments (Heron & Webster, 2019).

In the interview, students noted that scaffolding strategies made speaking practice more dynamic and enjoyable, as illustrated by one student's remark:

“Lecture is very helpful when providing guidance and direction in speaking skills. Become more confident and possess greater capabilities than before.”

The student emphasised that the teacher's support made them unafraid of making mistakes, as every error was clarified with the correct answer. As a result, the student assessed that their speaking ability had improved compared to before. One student stated:

“The most helpful aspects are modelling (the teacher provides examples) and feedback (correcting mistakes), because I am able to understand the correct methods while also learning from errors.”

The lecturer provides substantial assistance by offering examples (modelling), new vocabulary, and polite feedback. They consider modelling and feedback to be the most effective forms of support, as they allow one to understand the correct approach while also learning from mistakes. Similarly, another student described:

“For me, the most influential strategies are the Modelling and Feedback strategies. This support gives me confidence because I feel entrusted by the instructor, which motivates me to live up to that trust.”

When having difficulty explaining opinions during discussions, the teacher provides guiding questions and examples of sentence construction, thereby offering greater assistance to students. The most helpful strategy is modelling, as students can directly observe the sentence construction process and emulate it. One student agrees that the modelling strategy can enhance his speaking skills and noted:

“When having difficulty explaining opinions during discussions, the teacher provides guiding questions and examples of sentence construction, thereby offering greater assistance to students. The most helpful strategy is modelling, as students can directly observe the sentence construction process and emulate it.”

In addition to modelling, several scaffolding strategies help students improve their speaking skills, one of which is the feedback provided by the lecturer. One student illustrated:

“The lecture assisted me in correcting several incorrectly and rigidly phrased sentences, until I was eventually able to articulate English sentences correctly.”

Students consider feedback from teachers to be the most helpful strategy, as it makes them aware of their mistakes and enables self-correction. This sentiment is also shared by one student who stated:

“When the teacher corrects mistakes (provides feedback) and offers support, it makes me unafraid of making errors.”

Most students prefer that lectures provide examples and give direct feedback to correct mistakes. One student demonstrated:

“The most beneficial aspects were the modelling and feedback, which greatly enhanced confidence.”

Scaffolding in the form of modelling, feedback, and prompting has a consistently positive impact on the improvement of students' confidence, fluency, and speaking skills. Pishadast (2022) opined that scaffolding interventions significantly enhance students' speaking abilities. Kruk (2021) describes that real-time feedback and interactive dialogues reduce anxiety by creating a controlled yet authentic learning environment. In addition, Mahan (2022) believes that modelling involves guided walkthroughs where the teacher prompts students to define key terms and subsequently demonstrates an appropriate response. Individual differences mainly lie in which scaffolding strategies are most helpful (modelling vs. feedback) and preferences for teacher support versus independent practice. Teacher scaffolding has been proven effective through three main strategies: modelling, feedback, and prompting. Significant improvement is observed in formal examinations, such as the final test at the end of the semester. Before lectures applying scaffolding strategies, the average scores of students in the middle test speaking exam were below the target achievement of 3 on a 6-point scale, which is very low. The assessment tools for speaking skills encompass five components. These five components of speaking ability include (1) stress, (2) grammar, (3) vocabulary, (4) fluency, and (5) comprehension. The description of each component is organised on a scale of 1-6 points (Nurgiyantoro 2011). After the lecturer gave scaffolding treatment in the Intensive English class, the score of speaking skills has improved from an average of 3 to 5. One of the students stated that:

“I felt more confident during the final exam because I was more self-assured and accustomed to speaking in front of the class.”

During the final test at the end of the semester, most students experienced a noticeable increase in confidence, which can be attributed to growing speaking skills in the classroom and medical context. Anggadewi (2017) suggests that a successful strategy involves designing learning materials that cater to students' specific needs, which in turn boosts their confidence and motivation to learn. Furthermore, Taber (2017) contends that scaffolding goes beyond merely organising learning processes or activities; it also plays a crucial role in aligning tasks with learning objectives that students may find difficult to accomplish on their own. Similarly, Abedi (2022) concluded that scaffolding contributed to a notable enhancement in students' fluency, coherence, and use of vocabulary. Psychological factors play an important role in enhancing students' self-confidence in language proficiency, alongside the lecturer's role in providing direct modelling and feedback. According Harmawati to et al. (2024) state that psychological elements like fear of being judged and shyness further intensify these problems, leading to reduced participation in speaking activities. Consistent exposure to interactive learning activities, such as class discussions, modelling, role-play, and lecture feedback, contributed to the reduction of speaking anxiety and the enhancement of students' speaking performance. This gradual development of communicative competence and self-efficacy enabled students to approach the final exam with greater composure and focus, thereby facilitating more effective expression of ideas

and improved overall performance. Scaffolding greatly impacts learners' speaking abilities, fostering improvements in specific elements such as pronunciation and grammar, along with complementary aspects of communication like confidence and critical thinking (Evenddy et al, 2024). The lecturer applied scaffolding strategies after the midterm test, in which students had received unsatisfactory grades. Scaffolding strategies had a significant impact on improving speaking skills in English, especially through modelling and direct feedback, which in turn could enhance confidence and motivation. This improvement was evident in the final test assessment at the end of the semester.

Conclusion

Improving student speaking skills becomes the main objective of the teaching–learning process during the Intensive English class. Speaking is the central focus as it is important for both students and lecturers in DIV Anaesthesia at Universitas Muhammadiyah Banjarmasin. Scaffolding is an appropriate teaching–learning technique to support students' speaking skills. Classroom observations and interviews with students, along with the results of the final test, demonstrate that scaffolding techniques assist students in gaining confidence in speaking and in achieving the assessment targets at the end of the semester. The techniques that were most helpful to them were modelling and feedback from the lecturer, through which many students felt assisted by the modelling and feedback. The extensive range of scaffolding applicable to both content and language serves as further justification for its continued use. The observed improvements align with the Scaffolding in Second Language Acquisition theory and the Communicative Competence theory, as classroom activities were orally focused and encouraged students to produce spoken language. Future studies are recommended to explore new topics for implementing the scaffolding technique to further examine students' speaking development.

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STUDENT MOTIVATION AND CULTURAL AWARENESS IN LEARNING THE TOBA BATAK SCRIPT: THE ROLE OF MULTI-STAKEHOLDER SUPPORT

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Received: 12 October 2025; Accepted: 12 November 2025

Abstract

This study aimed to examine the motivation, interest, and cultural awareness of elementary school students around Lake Toba regarding learning the Toba Batak script, as well as the role of multi-stakeholder support in its revitalization. A descriptive quantitative design was employed, involving one class from five representative schools across five districts. Data were collected using a 20-item Likert-scale questionnaire covering student interest, motivation, perception, and environmental support for learning the Toba Batak script. The questionnaire was validated by experts and tested for reliability (Cronbach's $\alpha \geq 0.70$). Data were analyzed descriptively using mean scores and categorized into four levels: low, medium, high, and very high. Results indicated that students exhibited very high interest and motivation, with most mean scores above 3.40. Students viewed learning the script not only as a technical skill but also as a medium for preserving cultural identity. They preferred culturally contextual and creative learning methods, such as storytelling, games, and visual media. Challenges were identified in teacher competence and intergenerational practice, highlighting the importance of teacher training. Furthermore, strong support from schools, parents, government, and community collaboration was crucial for successful revitalization. These findings suggest that integrating the Toba Batak script into the curriculum, employing interactive learning strategies, strengthening teacher capacity, and fostering multi-stakeholder collaboration can effectively enhance students' cultural literacy and identity.

Keywords: cultural awareness, elementary education, motivation, Toba Batak script

Introduction

The Toba Batak script stands as a paramount cultural heritage of Indonesia, embodying the rich literary civilization of the Batak people in North Sumatra. For centuries, this traditional writing system has served as the principal vehicle for cultural and intellectual expression, manifest in diverse forms such as sacred manuscripts, personal correspondences, and religious ritual texts (Sihotang &



Sitanggang, 2022). Transcending its fundamental communicative function, the Toba Batak script encapsulates the worldview, social values, and intricate symbolic systems that profoundly shape the identity and indigenous wisdom of the Batak community.

However, recent decades have witnessed a substantial decline in the usage of the Toba Batak script. This erosion is largely attributable to the confluence of modernization, globalization, and the ascendancy of the Latin script within formal educational frameworks, which have progressively marginalized indigenous literacy traditions. Beyond merely impacting linguistic patterns, this transformation elicits considerable concern regarding the attenuation of cultural awareness and the diminishing intergenerational connection to ancestral heritage (Lubis & Bowo, 2022; Simanungkalit et al., 2025). Consequently, this pervasive trend portends a potential cultural identity crisis, exacerbated by the accelerating dynamics of global communication.

Extensive research underscores the crucial role of the Batak Toba language and script in safeguarding ethnic identity and conveying the cultural values of its community (Sitinjak & Harianja, 2022). Nonetheless, initiatives aimed at the preservation and revitalization of the Batak Toba script have, to date, been notably limited and fragmented. A key impediment stems from the inadequate integration of cultural preservation strategies with educational technology innovations, thereby hindering the intergenerational continuity of literacy in this script among the younger populace.

In response to this pressing challenge, research has increasingly focused on developing digital technology-based approaches to support the preservation of traditional scripts. One notable innovation is the development of mobile applications for Batak script recognition, powered by artificial intelligence algorithms (Simbolon et al., 2025), which holds the potential to significantly enhance accessibility and stimulate broader public interest in the Batak Toba script. These technological advancements, when integrated with comprehensive educational initiatives and robust cultural campaigns, offer substantial promise for strengthening the long-term viability of Indonesia's rich cultural heritage and linguistic diversity (Rajagukguk et al., 2022).

In 2022, UNESCO underscored the critical role of culturally-grounded education as a mechanism for fostering cultural resilience and safeguarding community identity amidst the pressures of modernity. This perspective aligns closely with ongoing efforts to preserve the Batak Toba script, which is recognized not merely as a traditional orthography but as an intrinsic component of Batak cultural heritage with the potential to significantly enrich the educational domain (Willian et al., 2023). Consequently, numerous studies and pedagogical initiatives have been undertaken to adapt Batak Toba folklore into contemporary instructional resources, particularly for English language acquisition within educational settings (Ginting et al., 2021; Sinamo et al., 2021). This methodological approach involves reprocessing traditional literary works into contextualized learning materials, which concurrently foster a profound connection between students and their cultural heritage while cultivating essential bilingual literacy competencies (Lubis & Bowo, 2022).

The revitalization of the Batak Toba script has increasingly leveraged technological advancements, complementing traditional pedagogical approaches. A

significant development in this regard is the creation of an artificial intelligence and machine learning-based script recognition system, which has substantially expanded public accessibility to this indigenous writing system. This innovation not only underscores the Batak Toba script's inherent adaptive potential but also facilitates its seamless integration into contemporary educational contexts, thereby securing its sustained relevance in the digital era (Napitu et al., 2022).

Building upon this background, the present research endeavors to analyze the degree of motivation and cultural awareness among elementary school students in the Lake Toba region concerning the acquisition of the Batak Toba script, recognizing its integral role in fostering cultural literacy and local identity. Additionally, this study seeks to elucidate students' perceptions regarding the pedagogical relevance of script learning within the framework of the Merdeka Curriculum, alongside assessing their needs and preferences for culture- and creativity-based instructional methodologies. Consequently, the anticipated outcomes of this investigation are expected to yield actionable recommendations for strengthening the preservation of local culture through the thoughtful integration of contextual, interactive, and culturally identity-reinforcing learning strategies.

Method

Type of Research

This study employs a descriptive quantitative design aimed at assessing the needs, motivations, and perceptions of elementary school students within the Lake Toba region regarding the acquisition of the Toba Batak script. This methodological approach enables a systematic characterization of students' engagement, their views on the script's cultural significance, and the broader environmental factors that influence its learning.

Population and Sample

The research population encompassed all primary school students across the Lake Toba region. A representative sample was subsequently drawn, consisting of one class from each participating school. To ensure comprehensive geographic coverage and broad regional representation, five schools were strategically selected, with each representing one of the five distinct regencies: SD N 173280 Lobu Siregar (North Tapanuli Regency), SD 176368 Gurgur (Toba Regency), SD N 030298 Simallopuk (Dairi Regency), SD Negeri Partuko Naginjang (Samosir Regency), and SD N 086 Nagasaribu III (Humbang Hasundutan Regency). The final selection of specific classes was performed using a purposive sampling method, specifically targeting those classes where students demonstrated active engagement in cultural literacy activities.

Research Instruments

The research instrument comprised a 20-item Likert-scale questionnaire, specifically developed to gauge students' interest, motivation, perception, and the environmental support conducive to learning the Toba Batak Script. Responses were solicited via a four-point Likert scale, which included options for Strongly Agree (4), Agree (3), Disagree (2), and Strongly Disagree (1). The instrument's design was predicated on determining the extent of student demand for script

acquisition, recognizing its crucial role in fostering literacy and preserving cultural identity.

Validity and Reliability Test

To ensure methodological rigor, the questionnaire's content validity was established via expert review by specialists in education and local culture. Concurrently, its reliability was ascertained using Cronbach's Alpha, with a coefficient of ≥ 0.70 set as the criterion for acceptable internal consistency. These comprehensive validation procedures collectively affirm the instrument's capability to consistently and accurately measure the designated research variables.

Data Collection Procedure

Prior to the commencement of the study, formal authorization was secured from the school administration, and informed parental consent was obtained for all participating students. These essential preliminary steps were taken to uphold research ethics and to ensure the voluntary and appropriate involvement of the student participants. Subsequently, data collection was conducted directly within the classroom environment, with the researcher present to facilitate students' clear and comprehensive understanding of each statement presented.

Data Analysis

Descriptive statistical methods, specifically the calculation of means and subsequent categorization, were employed to ascertain patterns concerning students' interest, motivation, perception, and the perceived support for learning the Toba Batak script. A four-tiered categorization system was established for the data, with score ranges defined as: 1.00–1.75 representing 'Low', 1.76–2.50 'Moderate', 2.51–3.25 'High', and 3.26–4.00 'Very High'. This comprehensive analysis yielded crucial insights into the extent of student needs and the critical contribution of external support—encompassing teachers, parents, educational institutions, and governmental agencies—to the ongoing revitalization of the Toba Batak Script.

Findings and Discussion

To determine the specific requirements for elementary school students in the Lake Toba region to learn the Toba Batak script, this research utilized a questionnaire instrument based on a Likert scale. This instrument incorporated 20 statements designed to evaluate key dimensions, including student interest, motivation, perception, and the presence of environmental support, all pertaining to the acquisition of Batak script as an essential element of cultural literacy.

A four-point Likert scale was employed, comprising response options weighted as follows: Strongly Agree (4 points), Agree (3 points), Partially Agree (2 points), and Disagree (1 point). To ascertain the overall disposition of student responses, the mean score for each statement item was computed. These mean scores were then classified into four distinct categories based on the following established thresholds: 1.00–1.75 (Low), 1.76–2.50 (Moderate), 2.51–3.25 (High), and 3.26–4.00 (Very High).

Table 1 presents a comprehensive overview of the questionnaire results, detailing the distribution of student responses, the corresponding mean scores, and the assigned need level category for each statement.

Table 1. Distribution of Scores from the Student Needs Questionnaire Regarding Toba Batak Script Learning (N = 213)

No	Statement	SS	S	KS	TS	Average	Classification
1.	I love learning Toba Batak script because it's our cultural heritage.	780	51	2	0	3,93	Very High
2.	Learning Toba Batak Script is relevant to strengthen students' cultural identity in the era of globalization.	744	78	2	0	3,90	Very High
3.	I want to know more about the Toba Batak script	672	129	4	0	3,83	Very high
4.	Toba Batak script makes me more familiar with Batak culture	756	69	0	1	3,91	Very high
5.	I would like to learn Toba Batak script at school as a special subject.	600	171	8	1	3,76	Very high
6.	Merdeka Curriculum is suitable for introducing Toba Batak Script to students	564	165	22	6	3,67	Very high
7.	My teacher needs to be taught how to teach Toba Batak Script well	432	183	61	14	3,20	High
8.	Learning Toba Batak script makes me love Batak culture more	692	102	10	1	3,86	Very high
9.	Learning while playing (for example through stories or songs) is more fun than just taking notes	484	222	34	1	3,69	Very high
10.	I understand Toba Batak script better if it is taught through Batak folklore.	540	201	22	0	3,74	Very high
11.	I am excited to learn Toba Batak script if it is associated with	528	228	6	2	3,74	Very high

	Batak customs (e.g. ceremonies, music)						
12.	Pictures and cultural objects (like ulos) help me remember the Toba Batak script.	596	165	6	6	3,78	Very high
13.	Learning the Toba Batak script makes me realize the importance of preserving regional culture	704	99	4	2	3,86	Very high
14.	If we don't learn the Toba Batak script, it will eventually disappear.	492	174	14	25	3,56	Very high
15.	I can talk to my grandparents using the Toba Batak script	364	237	46	20	3,16	High
16.	I want to use the Toba Batak script in my daily life (for example, to write my name in a book).	484	204	38	5	3,44	Very high
17.	Government must help schools to teach Toba Batak script	640	111	20	6	3,77	Very high
18.	Schools need to provide books and teaching aids to learn Toba Batak script	692	111	6	0	3,86	Very high
19.	My parents support me to learn Batak culture, including the Aksaranya.	596	183	4	1	3,86	Very high
20.	Schools and Batak communities must work together to keep the Toba Batak script alive	697	96	4	4	3,87	Very high

Analysis of questionnaire data, collected from 213 students, revealed overwhelmingly positive attitudes toward learning the Toba Batak script, with most indicators categorized as 'very high'. Specifically, 18 of the 20 statements (90%) registered an average score exceeding 3.40, while the remaining two items (10%) were classified within the 'high' category. These findings underscore students' strong endorsement of the Batak script's revitalization, perceiving it as an integral component of cultural identity rather than merely a writing skill. This perspective aligns with prior scholarship emphasizing the critical role of traditional scripts in

preserving cultural heritage and shaping student identity (Ginting et al., 2021; Lubis & Bowo, 2022). Furthermore, despite the potential of technology to serve as an innovative learning medium, persistent challenges in script preservation endure, a reality corroborated by the students' positive reception to revitalization initiatives (Willian et al., 2023). Collectively, these data indicate that students are both motivated and prepared to engage with the script. Therefore, revitalization initiatives are likely to achieve greater efficacy through comprehensive strategies, including robust teacher training, the development of innovative educational media, collaborative support from diverse stakeholders, and systematic integration into the curriculum, thereby strengthening cultural literacy and identity.

The statements "I enjoy learning Toba Batak Script because it is our cultural heritage" ($M = 3.93$) and "Toba Batak Script makes me understand Batak culture better" ($M = 3.91$) garnered the highest mean scores, indicating that students predominantly perceive the script as a vital source of cultural pride and a means to deepen their comprehension of Batak culture. Moreover, the statement "Learning Toba Batak Script is relevant for strengthening students' cultural identity in the era of globalization" ($M = 3.90$) further highlights students' acute awareness of the script's pivotal role in preserving self-identity amidst the pervasive influences of globalization. Collectively, these findings underscore that students view the acquisition of the Batak script not merely as a technical skill but fundamentally as an instrumental tool for maintaining cultural identity and fostering a comprehensive understanding of their heritage. This perspective resonates strongly with existing scholarship, which consistently advocates for the integration of cultural heritage into educational frameworks to enhance student engagement and fortify cultural identity (Ezz El-Din, 2019; Ginting et al., 2021).

Furthermore, student perceptions regarding the script's significance for cultural identity preservation underscore the challenges confronting the Batak Toba community amidst contemporary globalization, a point elucidated by Purba (2022). This finding further distinguishes itself from prior research, which predominantly focuses on the academic dimensions of instructional materials, by instead underscoring the vital role of active student engagement and the cultivation of cultural pride associated with the Batak script (Sihombing & Sukmayadi, 2024). The robust student endorsement for Batak Toba script instruction observed in this study, therefore, highlights a significant potential for cultural heritage revitalization. This can be achieved through educational initiatives that actively bridge the younger generation with their intrinsic cultural identity and ancestral wisdom.

High levels of learning motivation are discernible from students' responses to survey statements. Specifically, the statement "I want to know more about Batak Toba script" garnered a mean score of 3.83, while "I want to learn Batak Toba script in school as a special subject" received a mean score of 3.76. These results collectively underscore a strong desire for the formal integration of Batak Toba script instruction into the educational curriculum. Further supporting this prospect, the implementation of the Merdeka Curriculum received considerable endorsement ($M = 3.67$), thereby significantly enhancing the feasibility of integrating script learning. This collective sentiment highlights students' aspiration for more systematically structured cultural heritage education. This aligns with research by Martínez-Rodríguez et al. (2022), which established that integrating cultural

heritage components into the curriculum significantly fosters students' emotional engagement and contributes to identity formation. Furthermore, studies by Batmaz (2023) underscore that culturally informed education cultivates a deeper awareness and appreciation for both indigenous and global heritage. Consequently, the incorporation of the Batak Toba script into formal educational frameworks is poised to substantially contribute to cultural preservation and sustainability.

Moreover, this investigation underscores the considerable potential of innovative pedagogical strategies, particularly those leveraging digital technologies, to significantly enhance student engagement with cultural content (Ezz El-Din, 2019). While prior research, exemplified by Willian et al. (2023), predominantly focused on the technical dimensions of character recognition, the current study's findings critically illuminate the significance of student motivation and pedagogical relevance within cultural learning paradigms. Consequently, the outcomes of this study substantiate the notion that integrating the Batak Toba script into the curriculum not only fortifies students' cultural identity but also represents an efficacious strategy for revitalizing cultural heritage education amidst the challenges of globalization.

Students' learning method preferences reveal a pronounced inclination toward culture-based and creative pedagogical strategies, particularly those involving storytelling, gamification, or visual modalities. Empirical data from student responses further substantiates this tendency, with significant agreement observed for statements such as "Learning through play is more engaging than merely taking notes" ($M = 3.69$), "I achieve greater comprehension when instruction is delivered via Batak folk tales" ($M = 3.74$), and "Visual aids and cultural artifacts facilitate my recall of Batak Toba Script" ($M = 3.78$). These findings unequivocally underscore the pertinence of integrating ethnopedagogical strategies and contextually relevant instructional media. This observational evidence converges with existing scholarly literature, which consistently highlights the efficacy of ethnopedagogical approaches and visual media in fostering enhanced student engagement, deepening comprehension, and augmenting intrinsic learning motivation (Lestari & Wibawa, 2021; Mahisa et al., 2023; Manipuspika, 2020; Dos Santos, 2020).

While certain prior investigations, such as that by Nguyen and Boers (2019), predominantly focused on the technical dimensions of acquiring discrete content like vocabulary, the present research underscores the crucial significance of cultural integration and active learning experiences. These findings collectively suggest that pedagogical approaches rooted in contextual and interactive engagement not only facilitate deeper comprehension but also substantially reinforce learners' affiliation with their cultural heritage. Consequently, this study highlights the imperative for educators to devise engaging, efficacious, and culturally congruent pedagogical interventions that concurrently contribute to the preservation of cultural patrimony.

Students demonstrate a robust understanding and appreciation of cultural heritage, as evidenced by elevated mean scores for statements such as "Learning Toba Batak Script fosters cultural appreciation" ($M = 3.86$) and "Realizing the importance of preserving local culture" ($M = 3.86$). Conversely, assessments revealing lower mean scores for items pertaining to teacher pedagogical proficiency ("My teacher needs to be taught how to teach Toba Batak Script well," $M = 3.20$) and intergenerational linguistic transmission ("I can speak with my grandparents using Toba Batak Script," $M = 3.16$) underscore a perceived lack of adequate

instructor training and restricted avenues for transmitting the script across generations. These factors collectively constitute significant impediments to its successful revitalization.

These findings are consistent with the existing literature, which emphasizes the critical importance of comprehensive teacher training and the thoughtful integration of cultural values within educational paradigms (Hammime et al., 2019; Milian & Walker, 2019; Yücel & Yavuz, 2019). The demonstrated readiness of students to engage with the Batak Toba script further corroborates this view, highlighting the significant potential for effective educational reform when educators are equipped to bridge cultural divides and foster robust intergenerational communication. Consequently, a concerted effort to enhance teacher capacity is indispensable for ensuring the sustainable preservation and successful transmission of cultural identity.

The high mean scores attributed to the roles of the government ($M = 3.77$), schools ($M = 3.86$), parents ($M = 3.86$), and school-community collaboration ($M = 3.87$) unequivocally underscore the perceived significance of external support. This collective endorsement strongly suggests that the effective preservation of cultural scripts is contingent upon comprehensive multi-stakeholder collaboration. This observation is demonstrably consistent with established academic discourse on school-community partnerships, which frequently highlights the pivotal role of robust multi-party involvement in facilitating the successful implementation of culturally responsive and sustainable educational programs (Wyatt, 2010). Such an integrated, collaborative framework not only significantly enriches students' educational experiences but also cultivates a profounder sense of commitment to their cultural heritage.

The findings of the present study are further substantiated by Atashinsadaf et al., (2023), whose work underscores the critical importance of a concerted response among educators, parents, and the broader community in addressing pedagogical challenges. Collectively, these insights affirm that the successful revitalization of the Batak Toba Script is contingent upon an integrated multi-stakeholder support system to achieve its educational and cultural preservation objectives.

The findings of this research bear significant implications for pedagogy, cultural preservation, and educational policy. From a pedagogical standpoint, the study reveals a notably high level of interest and motivation among elementary school students in the Lake Toba region towards learning the Toba Batak Script. This observation underscores the imperative for formal integration of local script instruction into the educational curriculum. Educators must therefore develop innovative culture-based or ethnopedagogical instructional models, incorporating strategies such as storytelling, educational games, and contextual visual media, to foster more engaging and meaningful learning experiences. Moreover, comprehensive professional development for teachers is essential to equip them with the requisite competence to impart the Toba Batak Script, not merely as a system of writing, but critically, as a vehicle for inculcating cultural values and reinforcing local identity. The judicious integration of digital technologies and interactive media is also paramount to render the acquisition of this script more adaptive to the distinct characteristics of the younger generation immersed in the digital age.

Culturally, this research reveals that students perceive the Batak Toba script not solely as a technical proficiency, but also as a powerful emblem of cultural identity and ethnic heritage. The revitalization of this script thus represents a highly promising strategy for safeguarding Batak Toba cultural distinctiveness amidst the pervasive forces of globalization. Engaging with the Batak Toba script can bolster students' cultural literacy and character development, foster a profound sense of connection to their ancestral legacy, and facilitate intergenerational continuity through the active transmission of cultural values. Consequently, sustained collaboration among educational institutions, families, and indigenous communities is paramount for ensuring the enduring success of this vital cultural preservation initiative.

The observed substantial student receptivity towards learning the Batak Toba script, unequivocally supported by strong endorsements of the roles played by governmental bodies, educational institutions, and communities, underscores a compelling imperative for the establishment of more systematically structured policies to facilitate regional script revitalization. Consequently, it is incumbent upon local governments, in close collaboration with educational institutions, to formulate comprehensive revitalization programs that are seamlessly integrated into the Merdeka Curriculum. Furthermore, these efforts must proactively foster robust synergistic relationships among diverse stakeholders, specifically encompassing educators, parents, and cultural institutions. To ensure the effective and sustainable implementation of these initiatives, the systematic optimization of resource provision, including high-quality textbooks, accessible digital learning materials, and culturally relevant pedagogical media, is critically essential.

Theoretically, the findings of this study provide empirical support for the concept that ethnopedagogy and indigenous wisdom-based learning are pertinent approaches for enhancing learning motivation, strengthening cultural identity, and fostering active student participation within multicultural educational settings. Consequently, this research affirms that the revitalization of the Batak Toba script through both formal education and digital learning platforms constitutes a strategic imperative for reinforcing the cultural literacy, ethnic identity, and local pride of the younger generation in the Lake Toba region. The successful execution of this endeavor is critically contingent upon the preparedness of educators, robust governmental policy support, and the proactive engagement of local communities and cultural organizations, which together form the fundamental pillars for preserving the Batak Toba cultural heritage.

Conclusion

The research findings indicate that elementary school students residing in the Lake Toba region exhibit a profound interest, robust motivation, and heightened cultural awareness regarding the acquisition of the Batak Toba script. This observation is strongly supported by quantitative data, where the vast majority of questionnaire items yielded mean scores exceeding 3.40. These scores affirm that students perceive script learning not merely as a foundational writing skill, but critically, as an indispensable means for safeguarding their cultural identity and heritage. Such pronounced learning motivation, coupled with strong endorsement for the script's integration into the curriculum—particularly within the framework

of initiatives like the Merdeka Curriculum—underscores students' notable readiness for more structured and culturally resonant pedagogical approaches.

Students consistently demonstrate a preference for learning methodologies that are both creative and culturally embedded, particularly those incorporating elements such as folklore, traditional games, and visual media. This inclination strongly affirms the pertinence of employing ethnopedagogical strategies and utilizing contextually appropriate instructional materials. Despite students exhibiting a high degree of cultural appreciation, significant challenges persist concerning teacher competency and the integration of cross-generational practices. Consequently, robust teacher training programs are indispensable for effectively supporting script revitalization initiatives. Furthermore, the successful preservation of the script is critically contingent upon multifaceted external support, encompassing governmental backing, institutional commitment from schools, active parental involvement, and robust collaboration between schools and the wider community. Overall, this research unequivocally confirms that the revitalization of the Batak Toba Script can be most effectively achieved through a comprehensive approach involving curriculum integration, the adoption of contextual and interactive learning methodologies, significant enhancement of teacher capacity, and synergistic multi-stakeholder collaboration to bolster students' cultural literacy and reinforce their identity.

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REFORMULATING EDUCATION POLICY THROUGH DIGITAL LITERACY FOR DIGITAL VIOLENCE PREVENTION

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Received: 30 October 2025; Accepted: 18 November 2025

Abstract

This study aims to analyze how digital literacy becomes part of educational policy in the digital era in preventing digital violence in the school environment. Digital literacy is analyzed by looking at four main dimensions: digital skills, digital ethics, digital culture, and digital security. Using a qualitative approach with a case study method, which is then analyzed using coding techniques. Primary data were obtained from interviews with teachers and students in junior high schools in Bandung City. Secondary data was obtained from various educational policies related to the prevention of digital violence in Indonesia. The results show that the rise of digital violence, along with current digital developments, is not supported by educational policies specifically regulating the prevention of digital violence. The problems of bullying on social media, online games, and the excessive use of AI have not placed children in a safe position when interacting in the digital space. The application of digital ethics and digital security has not been a focus of strengthening digital literacy, so children are only directed to understand the mastery of technical skills using digital technology, without being balanced with moral awareness and social responsibility.

Keywords: digital literacy, digital space, digital violence, educational policy, violence prevention

Introduction

The potential for violence in digital media not only threatens adults but also children. Digitalization has brought about major changes, one of which is the uncontrolled flow of information, raising challenges regarding how child protection should be implemented in the digital world. The digital world has become a complex, limitless space for children, not only providing learning opportunities but also carrying risks that threaten their safety and well-being (Jang & Ko, 2023; Guštin, 2022). Easy access to digital media without supervision increases the risk of children being vulnerable to negative influences rather than positive ones.

The Disrupting Harm research report conducted by ECPAT International in collaboration with INTERPOL and UNICEF in 2022 stated that 2% of children in Indonesia aged 12-17 years were targets of online sexual exploitation and harassment. In 2024, the Deputy for Special Protection of Children at the Ministry of Women's Empowerment and Child Protection also revealed that, during the period of January-September 2024, there were 7,000 child protection complaints regarding digital violence (Mardianti, 2024). SAFEnet Indonesia data also recorded a fourfold increase in digital violence cases in the first quarter of 2024, of which



26% of the victims were children under 18 years old (Pratiwi, 2024). Malihah and Maftuh (2024) also revealed that children have the potential to become perpetrators of violence in the digital realm, one of which is cyberbullying. This shows that children are not merely victims but have the potential to become perpetrators of violence in the digital realm. Children have the potential to become actors vulnerable to reproducing patterns of violence in the digital ecosystem.

The problem of digital violence is certainly not directly proportional to data on children's internet consumption. The Indonesian Internet Service Providers Association noted that, of the 79.5% of internet users in Indonesia, 34.40% are children. This makes the problem of digital violence out of sync with the level of knowledge about wise internet use, making the problem of violence in the digital realm unavoidable. Regulations supporting internet safety in Indonesia, especially for children, are also considered inadequate, which indirectly exacerbates the potential for violence in the digital realm. Without adequate protection, the long-term impact refers to threats to child protection that also disrupt their psychological and social development (Smokowski & Evans, 2019). When children become victims or perpetrators of violence, it impacts their social interactions. Child victims of violence also often withdraw from their environment to the point of experiencing symptoms of anxiety and trauma.

Education plays a central role in preparing quality human resources to create a dignified nation. The humanization process internalized through education aims to become a platform for the formation of personality values and norms towards a superior and competitive generation (Hidayat, 2021). The widespread use of technology in today's digital era is certainly commonplace in educational activities, as improving the quality and relevance of education must align with global demands. Law Number 59 of 2024 concerning the 2025-2045 National Long-Term Development Plan states that learning needs to be directed toward digital-based learning that utilizes digital technology for learning innovation (pedagogical technological content knowledge). Therefore, to achieve the golden generation of 2045, learning needs to guide and shape children who are not only digitally savvy but also aware of their rights and responsibilities in the digital world.

Law Number 59 of 2024 concerning the National Long-Term Development Plan for 2025-2045 also states that education needs to focus on improving the quality of learning by integrating soft skills, social skills, and life skills, which is expected to be one way to prevent violence. In this digital era, these three skills can be emphasized through the development of digital literacy skills. As the world continues to change, digital literacy is becoming a critical component that not only supports academic success but also supports 21st-century skills (Astutiningsih et al., 2025). These digital literacy skills are important because students will be able to receive information wisely and critically using digital media.

In the 21st century, digital literacy skills are the foundation for responding to current developments in technology, information, and communication. According to Sulianta (2020), digital literacy can be interpreted as a skill that is as important as the ability to write, read, and calculate, so this skill is very important to have to support the current modern information era. The Ministry of Communication and Digital of the Republic of Indonesia explains that there are four pillars of digital literacy dimensions, including: (1) digital skills; (2) digital ethics; (3) digital culture; and (4) digital safety. These four pillars of digital literacy dimensions

provide provisions for individuals to face the complexities of life in the current digital era, so it is hoped that these four pillars will become skills that support the 21st century.

In 2022, Indonesia's digital literacy index recorded a score of 3.54% on a 5% scale, equivalent to a moderate level, with a breakdown of digital skills scores of 3.52, digital ethics of 3.68, digital culture of 3.84, and digital safety of 3.12 (Azis, 2024). Of the four pillars of the digital literacy index, the digital safety dimension still does not show a satisfactory score. This finding aligns with the development of cases of violence in the digital realm, which continues to increase. The occurrence of violence in the digital realm is also analogous to problems in the middle of the wilderness, depicting a complex, unpredictable phenomenon and harboring hidden threats. The lack of digital literacy explains that every individual needs to be aware of the importance of digital safety, which consists of an understanding of data protection and privacy rights.

The purpose of this study is to analyze how digital literacy becomes part of educational policy in the digital era to prevent digital violence in the school environment. The role of education is needed to fill the gap by promoting digital literacy learning that is internalized in educational policy in schools. The urgency of this research is based on the increasing cases of digital violence among students, which has not been fully addressed in educational policies and practices in schools. Although digital literacy has been introduced among students, its implementation is often technical in understanding digital skills and has not yet addressed aspects of ethics, security, and digital empathy. This study can indirectly analyze how digital literacy can be systematically integrated into policies and learning so that schools are able to prevent digital violence.

Method

This research employs a qualitative approach with a case study method. The focus of the research is to examine the phenomenon of digital violence among students, which presents a dynamic problem in schools. Digital literacy is relevant to the goals of 21st-century education, but on the other hand, there is the potential for digital violence to occur. The research examines the perspectives of informants, including their views, experiences, and practices, which are interpreted in line with the research objectives. The choice of a qualitative approach with a case study method is based on the complexity of the current digital violence problem, which is like a 'jungle', thus requiring an in-depth study.

The social setting of the research was conducted in four junior high schools in Bandung City, with the research location considering the 2024 Bandung City Education Report, indicators of educational unit programs and policies on bullying and violence in schools. The selection of schools looked at the categories of schools with high, upper middle, lower middle, and lower scores, so that the research captured the relevance of educational unit programs and policies to efforts to prevent and handle cases of violence. Informants in this study consisted of teachers and students as primary data to examine the problem of digital violence that occurs in schools and how programs and policies for preventing and handling cases of violence are implemented.

Data collection was conducted using two sources. Primary data was collected through in-depth semi-structured interviews with teachers and students, examining

their understanding of digital literacy, their attitudes and perceptions toward digital interactions, their experiences facing or witnessing digital violence, and the prevention and handling efforts implemented in the school environment. Secondary data also complemented the research data, which was conducted through a literature review of national education policy documents and child protection regulations in educational institutions. Data analysis was conducted thematically using coding techniques ranging from open coding, axial coding, and selective coding. These three stages were coded according to the relationships between categories, allowing for the formulation of research findings that focus on reformulating education policy through an understanding of digital literacy as a preventive measure in preventing digital violence in schools. Data validity was also carried out through triangulation of data sources and data collection techniques, which was also supported by a member checking process to ensure the accuracy of data interpretation.

This research has received ethical approval from the Research Ethics Committee, Universitas Pendidikan Indonesia, with ethical approval number 250/UN40.K/PT.01.01/2025. Participants were also provided with written informed consent. For students under the age of 18, parental consent was obtained at the start of the study.

Findings and Discussion

Educational Regulatory Framework in Digital Violence Prevention

Regulations in preventing digital violence aim to build a safe environmental ecosystem while simultaneously fulfilling children's rights and welfare. Protection of children from all acts of violence, abuse, and neglect is stipulated in the Convention on the Rights of the Child, which states that children have the right to receive protection from all forms of violence that threaten their well-being. This principle is what makes regulation considered the normative responsibility of the state in carrying out preventive efforts to prevent digital violence that occurs to children. Law Number 59 of 2024 concerning the National Long-Term Development Plan for 2025-2045 states that the issue of child protection is one of the policy priorities in order to realize sustainable human development and create a golden generation in 2045. This is one of the strategic programs in which strengthening the child protection system and preventing violence against children is a government concern.

Digital violence is understood as a new form of violence and an extension of conventional forms of violence that have developed along with the development of digital technology. Digital violence does not occur in physical violence, but rather online violence, ranging from cyberbullying, digital identity theft, digital sexual exploitation, doxxing, the distribution of content and information without consent, and other issues that occur on digital communication platforms and media. The occurrence of digital violence occurs without spatial boundaries, making it a wilderness problem that spreads rapidly without control mechanisms (Afzal et al., 2024). The impact of digital violence is a serious threat that occurs when students are required to have adequate digital skills, but the digital space does not provide security for children. This situation places children at vulnerability and at risk of exposure to violence that occurs not only in students who have critical digital literacy skills (Kalmus et al., 2024).

The existence of a legal framework should be a foundation that strengthens the boundaries of norms, educational responsibilities, and protection mechanisms. Child protection regulations in the digital realm are also considered inadequate, with current child protection regulations limited to Law Number 45 of 2008 concerning Pornography, Law Number 12 of 2022 concerning Criminal Acts of Sexual Violence, Law Number 27 of 2022 concerning Personal Data Protection, and Law Number 1 of 2024 concerning the Second Amendment to Law Number 11 of 2008 concerning Electronic Information and Transactions. Child protection regulations in the digital realm require special attention as children's activities in the digital space increase, making the absence of these regulations a challenge to the current reality. The use of digital technology by children presents not only opportunities but also challenges that demonstrate the heterogeneity of the discourse on children's digital rights from a phenomenological perspective (Newland et al., 2018).

Regulations governing and ensuring children's activities in digital spaces should provide a legal framework for preventive, pedagogical, and digital space governance strategies that can be implemented within educational institutions. Educational institutions need to develop a protective environment that includes safeguarding, codes of ethics, rules for the use of technological devices, mechanisms for reporting digital violence, and continuous digital literacy in the education process (Arsalani et al., 2022). However, schools often face challenges in the government's legitimacy process, which leads to clear guidelines for protection policies. Schools can become part of a collaborative multisystem to prevent digital violence as a preventive measure (Jackson & Viljoen, 2024). The educational regulatory framework for digital violence prevention can be implemented sustainably, hierarchically, and systematically. Educational regulations must be directed toward creating a safe, inclusive, and empowering digital culture, where children are not only protected but also able to protect themselves and others through competent digital literacy skills.

Students' Digital Literacy Patterns and Problems

The use of digital technology has become a part of life for children growing up in today's digital era, who are considered digital natives. While children are expected to be up-to-date and understand various digital technologies, this can present a duality between opportunities and risks (Henze-Pedersen & Kirkegaard, 2025). Opportunities can be seen in how digital technology can be beneficial in supporting communication and social connectedness, independent learning, and even fostering creativity. At the same time, digital technology presents the potential for children to be vulnerable in an overly expansive space, placing them in the position of being both victims and perpetrators of digital violence.

Preventive efforts that schools can undertake include conducting learning that strengthens digital literacy understanding. Digital literacy is not only the knowledge, skills, and attitudes that enable children to develop and progress in an increasingly global digital world, safely and empowered, in ways that are appropriate to their age, culture, and local context (Yue, 2022). From a learning perspective, digital literacy is considered the ability of students to use digital devices and technologies for work, learning, and interaction. On the other hand, the European Framework for Digital Literacy (EFDL) defines digital literacy as an

individual's awareness, attitude, and ability to use digital tools and facilities appropriately to identify, access, manage, integrate, evaluate, analyze, and synthesize digital resources, build new knowledge, create media expressions, and communicate with others, within the context of specific life situations, to enable constructive social action; and to reflect on this process (Tang & Chaw, 2016).

Digital literacy manifests as cognitive and technical skills that enable individuals to access, understand, evaluate, and use information effectively through various digital platforms. The scope of digital literacy, which is expanding along with technological advances, can mean that literacy develops along with the development of ethical issues that arise in the digital space (Astutiningsih et al., 2025). Digital literacy is positioned as a multifaceted knowledge and skill that develops ways of thinking that are useful now and in the future. These digital literacy skills encompass not only technical abilities such as operating software or hardware, but also involve critical thinking in assessing the reliability of information sources, understanding the ethical implications of technology use, and being able to communicate and collaborate productively in digital spaces. With good digital literacy, one can utilize technology to improve the quality of life, both in the context of learning and social interactions (Kateryna et al., 2020).

Today's students are familiar with digital technology and generally know how to access, create, and share digital information. Tang and Chaw (2016) argue that to be digitally literate, one needs to be able to not only search and manage, but also research and integrate digital information. Although today's students are generally considered tech-savvy, many of them find it difficult to do so effectively. Students need to acquire planning, monitoring, and control skills related to information management, as well as critical thinking skills. The idea that to be digitally literate, one not only knows how to find information from the web, but also has the ability to understand and organize information from various print or digital sources.

The ongoing issue of digital violence undoubtedly impacts the continuity of classroom learning. When students become victims or perpetrators of digital violence, it can indirectly disrupt their learning and social relationships. Education today needs to integrate digital literacy principles that can guide students in using digital technology wisely. Learning in the digital era must prepare students to face future challenges, which require not only cognitive knowledge but also critical and creative thinking skills. Students are expected not only to protect themselves from the threat of digital violence but also to be active in the digital environment and use digital technology wisely and positively.

Based on research results, the implementation of digital literacy for students is still instrumental and technocratic. This means that students have adequate digital skills, and policies focus on improving the practice and knowledge of using digital technology rather than understanding aspects of digital ethics, digital culture, and digital security. Consequently, digital literacy has not fully functioned as an instrument of protection and empowerment for children, especially in preventing increasingly complex and evolving digital violence (Livingstone et al., 2022). The root of the problem is that digital literacy is still defined narrowly, so that students focus on using sophisticated digital technology. This contrasts with how digital literacy should direct students to develop critical skills in online activities, have an awareness of protecting personal and other people's data, and be able to apply ethics and norms of politeness in communicating online. Digital literacy is only a technical

skill, without being interpreted with the urgency of equipping students to assess and take protective actions in online spaces during interactions (Arsalani et al., 2022).

The implementation of digital literacy has not yet addressed how to develop critical and reflective awareness when students use technology beyond just technical skills. While technical skills in using digital technology can be learned quickly and easily, digital ethics, digital culture, and digital security require a continuous, experience-based process (Anurogo et al., 2023). Understanding that digital literacy encompasses more than just how to use technology, it also encompasses why and for what purpose it is used. Digital literacy must be able to shape empowered, critical, and responsible individuals, enabling children not only to interact safely in digital spaces but also to build an inclusive and ethical digital culture.

Conclusion

Reforming education policy amidst the current development of digital technology needs to focus on strengthening digital literacy, which can be used as a preventive measure in preventing digital violence in educational environments. Although the presence of regulations is a gap in this research, it has not yet fully provided a sense of security for students interacting in online media. The implementation of digital literacy is also still limited to instrumental and practical matters, not reflective ones. Schools can direct preventive efforts that not only focus on strengthening digital skills, but also need to guide students in how they need to be critical, have ethical awareness and digital security, and have a sound understanding of digital culture. These four elements of digital literacy can serve as a reference for student behavior standards in interacting online. Reforming education based on digital literacy provides input that positions schools as part of a multisystem in the digital ecosystem, thus ensuring students are not only protected but also able to protect themselves and others in the digital space.

Acknowledgement

This research was funded by the Basic Scheme Research Grant for the Scope of Postgraduate Dissertation-Doctoral Research by the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia, in the 2025 budget year between the Directorate of Research and Community Service, Directorate General of Research and Development and the Indonesian University of Education Number 101/C3/DT.05.00/PL/2025.

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THE LEARNING PROCESS REQUIRES COLLABORATION

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Received: 1 November 2025; Accepted: 18 November 2025

Abstract

Learning is not only an individual process; it also requires the involvement of others. Collaboration is crucial for students to exchange ideas and help each other understand the material. The method used in this research is a literature review. Data and information were obtained from five journals and two books, which served as primary sources. Papers indicate that collaboration-based learning models, such as project-based learning (PBL), project-based learning (PjBL), Team-Assisted Individualization (TAI), and online collaboration, significantly improve students' collaboration skills. Improvements were seen in aspects of contribution, time management, problem-solving, cooperation, and investigation, with percentages consistently improving from the pre-cycle to the second cycle, according to the research cited. Collaboration has also been shown to develop critical thinking skills, creativity, social skills, and learning motivation. Teacher and parental support, and the use of digital technology, play a significant role in the success of collaborative learning. It can be concluded that learning is not only related to understanding the material, but also involves interaction and collaboration among students. Through collaborative learning, learners can learn from one another, appreciate differences, and collectively construct a deeper meaning of learning. With the support of digital technology, this approach can create an active, participatory learning environment relevant to the demands of 21st-century education.

Keywords: collaboration, digital technology, learning, problem-based learning, project-based learning

Introduction

In today's education system, the learning process no longer solely emphasizes individual abilities but also demands the ability to collaborate with others. Collaboration is key to successfully understanding material, solving problems, and developing student creativity. Collaborative learning facilitates students' sharing of ideas, discussions, and joint solutions, enabling them to develop a deeper understanding of a concept. Without collaboration, the learning process often becomes an individualistic activity, lacking in interactivity, and unable to address the complex challenges of 21st-century education, which demands critical thinking, communication, collaboration, and creativity.

21st-century education requires students to master not only cognitive aspects but also social and emotional learning skills. According to Trilling & Fadel (2012), one of the four core skills known as the 4Cs (Critical Thinking, Creativity, Communication, and Collaboration) is the ability to collaborate. This indicates that



collaboration is not merely an additional activity in the learning process, but a core competency that students must master to adapt and contribute effectively in a dynamic and interconnected global society.

Self-directed learning is a conscious process that produces changes in a person, whether in terms of knowledge, attitudes, or behavior. These changes are permanent and occur through experience and the individual's interaction with their environment. According to Setiawati (2018), learning is a deliberate activity that creates behavioral changes that differ from previous ones. This demonstrates that the learning process aims not only to acquire knowledge but also to shape an individual's character, social skills, and mindset, enabling them to adapt to various situations and social environments.

The term collaboration comes from Latin, from the words *co*, meaning "together," and *labor*, meaning "work." Simply put, collaboration can be defined as the activity of working together to achieve a mutually agreed-upon goal. In an educational context, collaboration describes the process of cooperation between students and between teachers and students in solving a problem or learning assignment. Through collaboration, students learn to respect each other's opinions, build effective communication, and develop critical and creative thinking skills (Supratman, 2021). Thus, collaboration not only teaches students how to work together but also fosters empathy, tolerance, and a sense of responsibility towards the group.

Furthermore, Vygotsky's sociocultural theory provides a strong foundation for the application of collaboration in learning. Vygotsky emphasized the importance of social interaction in the process of knowledge formation. The concept of the Zone of Proximal Development (ZPD) explains that students can achieve higher levels of understanding through assistance or collaboration with others who are more experienced. In the context of collaborative learning, the teacher acts as a facilitator who guides students to learn together, while students help each other understand the material. Thus, the collaborative process becomes an effective means of achieving optimal cognitive development.

Numerous studies have also shown that implementing collaboration in learning has a real positive impact. Research by Hartina et al. (2022) in the *Journal of Education and Learning*, entitled "The Impact of Problem-Based Learning on Improving Collaboration Skills in Thematic Learning," shows that the PBL model can significantly improve collaboration skills among students. The implementation of this model encourages students to discuss, exchange ideas, and find solutions together. These findings reinforce the view that collaboration is not just a method, but an integral part of an effective and meaningful learning strategy.

The benefits of collaborative learning are not only evident academically, but also socially and emotionally. Through collaboration, students learn to develop empathy, self-confidence, communication skills, and conflict resolution skills. Teachers also benefit by creating a more dynamic, open, and participatory classroom atmosphere. However, implementing collaboration in learning also faces challenges, such as differences in student ability, low participation among some group members, and teachers' lack of skills in managing group dynamics. Therefore, appropriate strategies and approaches are needed for collaboration to be effective and positively impact learning outcomes.

Based on this background, this article aims to explain the importance of collaboration in the learning process and outline how the implementation of collaborative learning can improve the quality of learning and student learning outcomes. Furthermore, this discussion will highlight the role of teachers, learning models that support collaboration, and the challenges that need to be overcome to create a truly collaborative and effective learning process in the modern education era.

Method

This article, entitled "The Learning Process Requires Collaboration," uses a literature review to collect and analyze various scientific sources discussing the importance of collaboration in the learning process. Literature search as a source was conducted using the Google search engine with the keyword 'the learning process requires collaboration'. This method was chosen to gain a deep understanding of the concept, benefits, and application of collaboration in improving student learning effectiveness. Data was collected from scientific articles, educational journals, research reports, and relevant reference books, then analyzed to identify basic theories and proven effective collaborative learning practices. The results of this literature analysis serve as the basis for explaining the role of collaboration as a modern learning strategy that fosters students' critical thinking, communication, and social cooperation skills.

Findings and Discussion

The Meaning and Importance of Collaboration in the Learning Process

Collaboration in the educational context is a process of working together between individuals or groups to achieve shared learning goals. According to Triling & Fadel (2012), collaboration is included in the four key 21st-century skills known as the 4Cs (Critical Thinking, Creativity, Communication, and Collaboration). These four skills are considered essential for equipping students to face increasingly complex global challenges. Collaboration is the foundation for developing critical thinking and communication skills, as in the process, students learn to listen, respond, and synthesize ideas to generate shared solutions.

According to Supratman (2021), collaboration in learning not only focuses on improving academic understanding but also honing students' social and emotional skills. Through collaboration, students learn to respect others' opinions, adapt to differences, and develop empathy. This aligns with Vygotsky's sociocultural theory, the concept of the ZPD, which explains that a person's cognitive abilities can develop optimally when they interact and collaborate with others who are more experienced (Vygotsky, 1978). In the learning context, teachers and peers act as "more knowledgeable others" who help students achieve higher levels of understanding.

Collaboration also fosters character values such as responsibility, honesty, and caring. In the process of working together, students are faced with situations where they must share tasks, reconcile differences, and resolve conflicts constructively. These values make collaboration a vehicle for character formation and the development of 21st-century skills. Therefore, collaboration is not just a learning method, but also a strategy for instilling humanitarian, social, and professional values in students.

Furthermore, collaboration supports meaningful learning, where students actively construct knowledge through interactions with their social environment. In collaborative learning, students are not merely recipients of information, but also creators of meaning with their peers. This process enriches understanding because students not only listen to the teacher's explanation but also engage in dialogue, questioning, and reinterpreting information based on their group's experiences.

Benefits of Collaboration for Student Learning Processes and Outcomes

The implementation of collaborative learning offers numerous benefits, both academic and non-academic. Academically, research by Hartina et al. (2022) demonstrated that the PBL model, which integrates collaborative elements, can improve students' conceptual understanding and critical thinking skills. In this model, students actively participate in group discussions to identify and solve real-world problems. The interactions that occur during the discussion process encourage the emergence of new ideas and strengthen understanding of the concepts being studied.

Research by Zhang and Ma (2023) also shows that implementing PjBL significantly improves students' collaborative skills. Through group projects, students learn to manage time, divide tasks, and manage differences of opinion productively. Furthermore, project-based learning fosters a sense of responsibility for the results of collective work. This demonstrates that collaboration not only strengthens cognitive learning outcomes but also builds mutual trust and solidarity among group members.

The Team-Assisted Individualization (TAI) model, as described by Tinungki et al. (2022), combines an individual approach with group work, allowing students to learn independently while sharing knowledge with their classmates. This model enhances mathematical communication skills, problem-solving skills, and confidence in collaborating. Through TAI, students not only rely on the teacher as the primary source of knowledge but also learn from each other, creating an active and participatory learning environment.

In addition to improving cognitive learning outcomes, collaboration also has a positive impact on learning motivation. When students work in groups, they tend to feel more motivated due to the social support and sense of community. Collaborative learning environments also increase emotional engagement, reduce boredom, and strengthen learning enthusiasm. Therefore, collaborative learning is an effective strategy for creating a fun and meaningful learning environment.

Effective Collaborative Learning Models and Strategies

Various collaborative learning models can be implemented to foster teamwork skills among students. One of the most widely used is PBL. This model emphasizes solving authentic problems relevant to everyday life. Through PBL, students are trained to think critically and creatively in solving problems together. This process requires intensive communication and clear role allocation within the group, so that each member is accountable for the team's work (Hartina et al., 2022).

Besides PBL, PjBL is also a highly effective strategy for enhancing collaboration. In PjBL, students are encouraged to develop, implement, and present project results in groups. According to Zhang & Ma (2023), project-based learning not only enhances collaboration but also develops students' managerial skills,

technical skills, and creativity. Projects designed in real-world contexts help students understand how collaboration is needed to solve challenges outside the classroom.

Another relevant model is TAI, which combines the advantages of individual learning and group collaboration. According to Tinungki et al. (2022), this approach allows students to learn at their own pace while still having room to discuss and exchange ideas with their group mates. The teacher, in this case, acts as a facilitator, monitoring group dynamics, providing feedback, and ensuring each student actively contributes.

In addition to these three models, collaborative strategies can also be realized through the use of digital technology. The use of online platforms such as Google Classroom, Padlet, Jamboard, and Microsoft Teams allows students to collaborate even when they are not in the same location. Digital collaboration opens up new opportunities in 21st-century learning, particularly in blended and distance learning situations. The use of online media also fosters digital literacy and communication skills across space and time.

Factors Influencing the Success of Collaboration in Learning

The success of implementing collaborative learning is influenced by various factors, both internal and external to the student. Internal factors include learning motivation, communication skills, and a sense of responsibility. Highly motivated students tend to contribute more actively to groups. Meanwhile, effective communication is key to successful collaboration, as open and empathetic communication can minimize conflict and foster collaborative development of ideas.

External factors include teacher support, the learning environment, and the availability of facilities and technology. Teachers play a crucial role as facilitators, systematically designing collaborative learning activities. They need to create an inclusive classroom atmosphere and encourage the participation of every student. According to Supratman (2021), teachers must also provide constructive feedback and instill the value of responsibility for group outcomes. Furthermore, support from parents and schools is essential to ensure a smooth learning process, particularly in terms of providing facilities and infrastructure.

The use of information and communication technology is also a crucial supporting factor in modern collaboration. Digital platforms can be used to share ideas, hold discussions, and work on group projects online. However, the success of digital collaboration depends heavily on students' digital literacy skills and access to adequate devices and internet connections.

Challenges and Efforts to Optimize Collaborative Learning

Despite its many benefits, implementing collaborative learning also faces various challenges. The main challenge that often arises is the lack of active participation from all group members. In some cases, some students tend to be passive and delegate responsibilities to others. This can lead to an imbalance in the workload within the group and reduce the effectiveness of collaboration.

Furthermore, differences in abilities and learning styles among group members can also be a barrier. Students with higher academic abilities may feel overwhelmed, while others may feel inferior or struggle to contribute. Therefore, it

is important for teachers to create diverse groups and foster a culture of mutual respect and support among members.

Limited facilities and access to technology are also significant obstacles, especially in online learning. Not all students have devices and a stable internet connection. To address this, schools need to provide supporting facilities such as computer labs and Wi-Fi access, as well as provide training for teachers and students to effectively utilize technology.

To optimize collaborative learning, several steps can be taken. First, teachers need to design activities that encourage active participation and group reflection, for example, through problem-based discussions, simulations, and joint projects. Second, teachers can develop collaborative assessments, where each student is assessed based on their individual contributions and group outcomes. Third, it is also important to provide social skills training, such as effective communication, conflict management, and shared decision-making, so that students are prepared to navigate complex group dynamics.

Implementing collaboration also requires ongoing monitoring and evaluation. Teachers need to monitor student interactions within groups to ensure there is no dominance or exclusion. Furthermore, teachers can facilitate reflection after collaborative activities so that students can learn from the experience and improve how they work together next time.

Implications of Collaboration for Education

The application of collaboration in learning has far-reaching implications for education, including improving the quality of the teaching and learning process, developing student character, and preparing them to face the demands of the 21st-century workforce. In the context of modern education, collaboration is no longer viewed as an additional activity, but rather as a fundamental necessity that supports active, meaningful learning and is oriented toward the development of 21st-century skills. According to Triling and Fadel (2012), collaborative skills are one of the key competencies in the 4Cs (Critical Thinking, Communication, Collaboration, and Creativity) that students need to master to adapt to future social and professional dynamics.

One of the main implications of implementing collaboration in education is improving the quality of social interactions and communication among students. Through group learning activities, students learn to listen, respond, and respect the opinions of others. This helps them develop interpersonal skills that are important not only in academic contexts but also in social life. Effective collaboration enables the creation of a democratic learning atmosphere, where every individual has an equal opportunity to actively participate. This learning environment reflects the values of fairness, empathy, and mutual respect—values that align with the national education goal of developing Indonesians with character and civility.

Furthermore, the implementation of collaborative learning also has positive implications for student motivation and engagement. When students work in groups, they feel a shared responsibility for learning outcomes. This situation fosters a sense of belonging to the learning process and strengthens intrinsic motivation. According to Vygotsky (1978), social interaction is a crucial component of cognitive development. By collaborating, students not only exchange information but also construct new knowledge through the process of negotiating

meaning and solving problems together. This makes the learning process more meaningful because students are directly involved in constructing their own understanding.

Another equally important implication is that collaborative learning can be an effective means of developing the soft skills needed in the modern workplace. Today's workplace demands individuals who not only possess high academic abilities but also the ability to work collaboratively in teams, communicate effectively, and think critically and creatively when facing complex challenges. Through collaborative classroom activities, students become accustomed to dealing with group work dynamics such as differences of opinion, division of tasks, and constructive conflict resolution. These experiences provide crucial capital for them in facing future professional realities (Zhang & Ma, 2023).

Institutionally, the implementation of a collaborative culture also impacts the transformation of the educational paradigm. Teachers no longer act as the sole source of knowledge, but rather as facilitators, assisting students in the process of exploring and constructing shared knowledge. Learning models such as PBL or Cooperative Learning are concrete examples of how collaboration is integrated into the learning system. Thus, collaboration not only shapes active and independent students but also fosters a participatory and innovative learning culture within the school environment (Tinungki et al., 2022).

From a broader perspective, collaboration in education contributes to the creation of an inclusive educational ecosystem. Through collaboration, schools can bridge differences in students' social backgrounds, cultures, and academic abilities. This cross-cultural interaction enriches the learning experience and fosters greater social awareness. Furthermore, the implementation of collaboration also strengthens the relationships between teachers, students, parents, and the community as part of a mutually supportive learning community. Thus, collaboration impacts not only individuals but also the education system as a whole.

Overall, collaboration in learning is not just a pedagogical strategy, but an educational philosophy that places social interaction and cooperation at the heart of the learning process. In the context of globalization and the ever-growing digital transformation, the ability to collaborate is key to creating an adaptive, innovative, and highly competitive generation. The application of collaborative principles in education ultimately contributes to the development of human resources who are not only intellectually intelligent but also socially and emotionally mature, ready to face the challenges and changes of the global era.

Conclusion

Collaboration in learning plays a strategic role in developing students who are not only intellectually intelligent but also socially and emotionally skilled. Through collaboration, students learn to interact, communicate, and solve problems together, ultimately improving the quality of their learning outcomes. Learning models such as PBL, PjBL, and TAI are likely effective in fostering collaborative skills while enhancing students' critical thinking and creativity.

The success of collaborative learning is influenced by various factors, including individual motivation, communication skills, the role of teachers, and support from facilities and technology. Despite facing a number of challenges, the

implementation of collaboration can be optimized through inclusive activity planning, social skills training, and ongoing evaluation.

Ultimately, collaboration is not only a learning method but also a vital part of character development and 21st-century competencies. Through collaborative learning, the world of education can produce a generation that is not only knowledgeable but also able to work together, appreciate differences, and contribute positively in social and professional life.

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“ONE SIZE DOESN’T FIT ALL”: DIFFERENTIATED INSTRUCTION IN MOBILE APPLICATION TO IMPROVE LISTENING PROFICIENCY OF INTERNATIONAL STUDENTS, A MIXED METHODS APPROACH

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Received: 9 October 2025; Accepted: 11 November 2025

Abstract

English as a Foreign Language (EFL) students in international classrooms possess different proficiency levels, making learning needs, styles, and readiness vary in various ways. The “one size fits all” strategy is not suitable to address this issue, especially in listening, the first important skill needed by EFL learners, which makes differentiation essential to be implemented. This study explores the impact and implementation of differentiated instruction in improving the listening proficiency of EFL learners in an international school. This convergent mixed-method study involved 29 students taking an online TOEFL class in an International senior high school. The scores of pre- and post-tests were analyzed using a paired sample t-test to examine students’ improvement in their TOEFL listening scores and proficiency levels. Content analysis of the participants’ learning journals and focus group discussions was used to find out how the differentiation was implemented. The results show significant improvement of the students’ TOEFL listening scores, leading to the improvement of their proficiency level through tiered materials in the English Listening Step-by-Step application, flexible grouping, and tiered assignments. Further study with a traditional face-to-face classroom and greater numbers of participants could be done to shed light on the effectiveness of differentiated instruction in improving English proficiency.

Keywords: differentiated instruction, listening proficiency, mobile-based application, standardized test, tiered instruction

Introduction

English as a Foreign Language (EFL) classrooms are often faced with students coming from various backgrounds with various learning needs, styles, and readiness. EFL context in international classrooms here in Indonesia, and probably any country in the world, different needs, readiness, and learning styles are the biggest challenges faced by teachers. This heterogeneous condition, which most often is neglected by teachers, disadvantages both lower proficiency and higher proficiency level students (Pozas & Letzel-Alt, 2023). Students with lower proficiency levels will struggle to survive in the classroom academically and socially. While higher proficiency level students often feel that the materials are not challenging enough, resulting in boredom and less motivation (Tajik et al., 2024). Even though these problems have long been recognized by teachers, solutions are often ineffective as teachers are often limited by the curriculum expectations and



time. Recent studies show that differentiated instruction has been used by teachers around the world to address different learning needs and readiness and promote personalized learning.

Differentiated Instruction is highly popular in education as it is reported to be effective in facilitating different learners' needs and learning styles in an effort to optimize learning and achievement (Pozas & Letzel-Alt, 2023; Langelaan et al., 2024; Kalinowski et al., 2024). In this sense, teachers are encouraged to proactively adjust their teaching to meet the learners' varied needs by differentiating their teaching instruction (Kahmann et al., 2022). Differentiated instruction has been employed by various classroom settings in the past two decades (Ardenlid et al., 2025). Implementing differentiated instructions in higher education settings where learners are very diverse has been proven effective in helping students to achieve their academic goals (Tulbure, 2011). A study performed by Nicolae (2014) has shown that with a differentiated instruction approach, students are greatly helped in achieving their learning goals while progressing at their best level. It has also shown positive outcomes when it is implemented in inclusive classrooms with gifted students (Ardenlid et al., 2025). Differentiated instruction not only helps students with learning difficulties to progress at their own speeds but also accommodates those fast learners to speed up their progress.

Differentiated instruction is highly popular in the teaching of a second and foreign language (Karadag & Yasar, 2010). Differentiated instruction significantly enhances their achievement in EFL writing in an environment where students have different proficiency levels and learning styles (Mohamed et al., 2025). Another study also suggested that teaching English as a foreign language using differentiated instruction could accelerate students' reading comprehension (Abdelmoula et al., 2019). A study on the use of tiered listening tasks of DI shows significant improvement in students' listening abilities (Pourdana & Rad, 2017). Another study focusing on the use of differentiated instruction combined with multiple intelligences in fostering students' listening comprehension also declared that this approach enhances students' listening abilities (Alavinia & Viyani, 2018). Studies have suggested that differentiated instruction is also popular to be adopted in teaching integrated listening skills (Palonga & Atompag, 2023). The result informed improvement of students' listening comprehension after imposing differentiation.

Despite the claims that differentiated instruction is effective in improving students' listening skills, research related to its implications on improving students' advanced listening skills in Standardized proficiency tests, such as the TOEFL listening test, is still limited. Most research focused on the use of DI in materials related to topics presented in guided books or student books (Pourdana & Rad, 2017; Alavinia & Viyani, 2018; Palonga & Atompag, 2023). Listening skill in TOEFL test is not only the skill to translate words, phrases, or sentences into their native language, but also to comprehend other aspects underlying the language (Mahlil, 2010; Yuliandani et al., 2014). Thus, specific strategies need to be used to gain high scores on the TOEFL test.

Many different strategies have been proposed to overcome the difficulty in TOEFL listening test. Philips (2003) has formulated some strategies for tackling TOEFL listening test that were compiled in a preparation coursebook. Philips formulated 3 different parts for TOEFL listening, with each focusing on short

conversations, longer conversations, and long monologues, respectively. However, the strategies presented in this book do not address learners with different proficiency levels (Al-Rawashdeh, 2011). A recent study on the use of TOEFL preparation strategies has reported that the strategies provided by the book are no longer relevant to the recent TOEFL test questions (Mustafa and Putra, 2020). Another study proposed watching videos and listening to music to improve listening comprehension ability. Though it might be useful in improving the general listening ability (Safranj, 2015) but it is time-consuming and often irrelevant to the topic and materials being tested in TOEFL (Mustafa & Putra, 2020). TOEFL Listening is more challenging compared to general listening, as it is designed to measure a certain level of English proficiency. Furthermore, students who take TOEFL preparation courses differ in their proficiency levels, so they need to learn different materials to improve their scores.

In addition, finding the right material for TOEFL listening practice on the internet is quite challenging. Aryadoust et al. (2024) mentioned that designing trustworthy and suitable listening materials is an expensive and labor-intensive process. Some researchers have shown that the advancement of technology, especially AI, has greatly helped teachers in formulating materials for English learning (Aryadoust et al., 2024). However, the challenge lies in selecting suitable materials that fit the level of proficiency of each learner (Safranj, 2015). Other research has proposed the use of mobile-assisted learning to help students easily obtain the materials (Mustafa & Putra, 2020). However, this involves selecting the right materials and arranging them in such a way that learners can easily access them. Therefore, a practical mobile application that suits all proficiency levels, such as “English Step by Step,” can be the best solution for both teachers and students. This study was guided by two research questions:

1. RQ 1: How effective is the differentiated instruction in the English Listening Step-by-Step application in improving TOEFL Listening score and listening proficiency of senior high school students?
2. RQ 2: How was the differentiated instruction in English Listening Step-by-Step application implemented in improving TOEFL Listening scores of junior high school students?

Differentiated instruction

Learning instruction can be called effective if it is able to address various learners’ needs and readiness (Sousa & Tomlinson, 2018; Kalinowski et al, 2024). One way to achieve this is by designing differentiated instruction (Sousa & Tomlinson, 2018; Schleicher, 2016). The Differentiated Instruction approach encourages teachers to actively modify the teaching methods, content, process, and environment to facilitate meaningful and effective learning for various students’ needs and backgrounds (Sousa & Tomlinson, 2018). Differentiated instruction expects teachers to consider students’ different conditions, including readiness, learning profiles, and interest (Sousa & Tomlinson, 2018). Students should be the main consideration for teachers in designing their differentiated instructions, as the main goal of DI is to help every student to optimize their potential in learning (Tomlinson, 2001; Compen et al., 2024).

Differentiated instruction is divided into process, product, content, and environment. Process differentiation means varying the learning activities used to

process or understand the material (Tomlinson, 2001). Product differentiation offers students various ways to show their learning, which allows for different levels of complexity and creativity (Belyaeva, 2023). Content differentiation involves varying the material students are expected to learn according to their readiness levels, interests, and figuration of learning (Tomlinson, 2001). Differentiating the learning environment involves adjusting the physical or psychological aspects of the classroom to support student learning (Heacox & Cash, 2019). Teachers who wish to implement differentiated instruction can design their teaching instructions using all four elements or adopt any of them based on the needs.

Differentiated content instruction is the process of modifying or adapting the what of teaching, such as topics, reading materials, or tasks, to match students' varied readiness levels, interests, or learning profiles (Tomlinson, 2001). This ensures that each student can access the curriculum and learn effectively. The purpose of differentiating content in teaching is to certify that all learners, regardless of their differences, have access to meaningful and appropriately challenging learning experiences (Tomlinson, 2001). Students come into the classroom with varying levels of prior knowledge and skills. Differentiating content allows teachers to provide more accessible material for those who need support and more advanced content for those who need enrichment (Tomlinson, 2001).

Differentiating content instruction is the most common form of differentiation adopted by teachers (Borja et al., 2015). Most teachers who implement this approach agreed that differentiating materials for different proficiency levels helps them develop at their best paces. In reading classes, content differentiation greatly enhanced students' reading comprehension (Abdelmoula et al., 2019). This study, which was performed in Morocco, also confirmed that students expressed their interest in reading when they were given different reading types based on their interest and readiness level. Differentiated content instruction has also been reported to be effectively helping non-English major students in Ukraine to improve their English proficiency level (Kupchyk & Litvinchuk, 2020). Another study on students' writing ability conducted in junior high school shows that differentiated content instruction significantly improved students' writing abilities (Argyropoulou & Zafiri, 2021). A similar result has been echoed by Mehany (2022) in the research in the EFL writing class. Those researchers have informed the effectiveness of differentiated content instruction in improving various skills in English language learning.

Differentiation of process in education refers to the adaptation of how students make sense of the material given by the teacher. Teachers modify the activities and strategies used to help learners process and internalize new information (Tomlinson, 2001). Process differentiation involves offering varied ways for students to explore the materials according to their readiness, needs, interests, and learning styles (Tomlinson, 2001). In English as a Foreign Language (EFL) teaching, process differentiation can be particularly valuable, as learners often have varied linguistic backgrounds, cultural contexts, and language acquisition speeds (Mehany, 2022). Teachers can implement flexible grouping, tiered tasks, learning centers, and interactive activities to accommodate these differences (Tomlinson & Imbeau, 2010).

In EFL classrooms, process differentiation enhances engagement and supports language acquisition by allowing learners to access materials in a manner

that is suitable with individual learning preferences (Widayanti et al., 2021). A recent study by Pozas (2022) showed that differentiated process instruction improved EFL students' motivation and autonomy. Similarly, Widayanti et al. (2021) found that students reported increased engagement when teachers used varied methods of materials delivery aligned with their learning needs. These outcomes suggest that tailoring the learning process in EFL classrooms leads not only to better linguistic competence but also to more inclusive and responsive teaching practices.

Standardized Test of English as A Foreign Language (TOEFL)

Standardized tests in English as a Foreign Language (EFL), such as TOEFL and IELTS, are structured assessments used to objectively measure proficiency in reading, writing, listening, and speaking. These tests serve as global benchmarks for academic admissions, certification, and employment (Educational Testing Service, 2020). Beyond individual evaluation, standardized testing contributes to the internationalization of English by promoting consistent language proficiency standards worldwide (Romero Villarroel & Camacho Estrada, 2018). Moreover, the impact of these tests extends to instructional practices and curriculum design. Studies have shown that the presence of standardized English tests can influence teaching methods, student motivation, and educational outcomes (Pan, 2019). Thus, standardized EFL tests play an important role in global education and professional mobility.

The Test of English as a Foreign Language, or TOEFL, is a standardized language test provided by the Educational Testing Service (ETS) to measure proficiency level. As one of the requirements for higher studies, the TOEFL test is highly regarded as important to most academicians (Mustafa & Putra, 2020). In job fields, TOEFL is one of the important requirements for job applications in government agencies, take care of licensing, or companies (Fitria, 2021). Romadhon (2022) states that in many countries around the world, TOEFL is used as an important requirement for university admission and for scholarship applications. Moreover, several Indonesian universities have made it mandatory for their students to submit TOEFL scores as part of graduation requirements (Mustafa & Putra, 2020). TOEFL is one of the standard requirements for enrolling as a graduate or postgraduate student in Indonesia (Romadhon, 2020). Furthermore, some universities in Asia also require the TOEFL as the main requirement for international students who are interested in enrolling in the universities.

There are some types of TOEFL tests, including IBT, CBT, and PBT. The type of TOEFL test that is highly popular in Indonesia is the PBT test, or widely known as TOEFL ITP, which measures three aspects, including listening, structure, and written expressions, and reading skills (ETS, 2020). The scores that can be gained by the test takers range between 310 to 677. Among the three aspects, the one regarded as the most challenging for test takers is listening skills. The listening section measures the understanding of spoken information used in academic (formal) and non-academic (informal) situations (Fitria, 2021). This section tests how much test takers understand conversations and monologues in English, which consist of short conversations, long conversations, and long monologues.

TOEFL Listening Section

The listening section of the TOEFL consists of 50 questions. It is meant to measure the understanding of spoken English in various modes of conversation and monologue (Gear & Gear, 2002). The section is divided into three subsections, namely the short conversation in section A, the longer conversation in section B, and the long lectures or monologue in section C. The time allocated to complete all 50 questions from the three subsections is around 25 minutes (Philips, 2003). In this section, the listening skills are intensely tested, considering the short amount of time that is allocated to complete the test.

Listening Comprehension on the TOEFL test is regarded as the most challenging aspect for test-takers, even for those who claim to be quite proficient in English (Fitria, 2021). Considering the time allocated to this section, which is very short, often puts pressure on the test takers. People who used to take notes of important information during a listening test often find the test to be hard to pass, as note-taking is not allowed (Fitria, 2021). Even so, among the three subsections, the first section is regarded as the least difficult by most test takers as it consists of around 30 short conversations followed by short questions after each conversation (Mustafa & Putra, 2020). Nevertheless, test takers still must face two more challenging subsections in longer conversations and long monologues.

Debates over whether listening strategies need to be taught to test takers have lingered during the past decade (Chen, 2010; Fathi et al., 2020; López, 2017; Sharaf et al., 2018). However, Nation and Newton (2009) argued that listening strategies are least likely to be effective and applicable to test takers of the TOEFL. Despite the debate, some language teachers agreed that listening strategies are useful for learners (Golubovich et al., 2018). Nevertheless, teachers still face many difficulties in teaching listening strategies to students, especially regarding TOEFL listening. Some of the problems might have to do with the types of questions given in the TOEFL listening and the inconsistency of topics and vocabulary. Thus, some strategies, such as using movies and songs as well as some AI tools, are not proven to be effective in helping students to pass the TOEFL listening test.

English Listening Step-by-Step Application

English Listening Step by Step - English Speaking is a free Android-based application that allows users to learn English listening. It helps users to easily listen to the pronunciation of every word in the English language (Softonic, 2022). The application includes audio and text on various topics (Google Play, 2023). The English Listening Step by Step application provides a huge number of lessons with different topics and difficulty levels (Softonic, 2022). Each lesson is organized into several sub-sections that include audio, vocabulary, translation, test, pronunciation, reading, and writing.

The words in the application are arranged into groups based on the difficulty level of pronunciation as well as the way they are pronounced in the English language (Softonic, 2022). The organization of the words in each subsection is designed for easy usage and to inform users of the way to use them. Those words can even be translated into the users' mother language. It is useful for people who are unfamiliar with the meaning of the words. The application contains two tests to measure the users' progress. The result can be used to plan the next step for the users to achieve the listening goals. Each word presented in the application is

pronounced by a native speaker in British and American voices. Each word is shown on the screen to allow users to highlight the words. It helps users remember the meaning easily. Thus, the English Step by Step applications allow users to freely select the topic that suits their level.

Method

Research Design

This study utilized a convergent mixed methods design, which uses both quantitative and qualitative data in parallelly. This design allows researchers to explore the effectiveness of differentiated instruction in enhancing learners' listening proficiency in English language learning (Creswell & Plano Clark, 2018). In this design, quantitative and qualitative data were collected synchronously, analyzed separately, and then integrated during interpretation to provide a comprehensive understanding of the instructional impact. The quantitative component involved pretest and post-test listening scores to measure changes in proficiency, while the qualitative strand consisted of student learning journals and focus group discussions to explore how they use the differentiation in English listening step-by-step application. The choice of a convergent design is justified by the need to obtain complementary insights; while quantitative data revealed the extent of improvement, qualitative findings helped explain how differentiated instruction influenced listening proficiency development. This design is particularly suitable for language education research, which explores complex constructs like language proficiency that benefit from both numerical evidence and contextual understanding (Creswell & Plano Clark, 2018).

Research Participants

This study involved 29 EFL learners in their twelfth grade of an international senior high school. Parallel sampling was used as this study involved only an experimental group. A single group is quite common in a convergent mixed methods study for qualitative and quantitative data collection (Plano Clark & Ivankova, 2016). All 29 participants completed a pretest and post-test of a listening proficiency test to determine changes in proficiency, and the same individuals also provided qualitative data through learning journals and participation in focus group discussions. This approach allowed the researcher to establish a direct correspondence between students' test performance and the way they use differentiated content in the application, strengthening the integration phase of the mixed methods process. The decision to use identical sampling is supported by Creswell and Plano Clark (2018), who argue that involving the same individuals across both data strands enhances comparability and coherence in interpretation. In line with best practices in language education research, parallel sampling also minimized logistical complexity while maintaining depth of insight (Ary et al., 2019).

Data Collection

Quantitative and qualitative data collection from the same experimental group were used in this study. The quantitative data were obtained through a pretest and posttest on the participants' listening proficiency. Pretest and post-test allow the researcher to closely explore the effectiveness of the approach used in this study

(Creswell & Plano Clark, 2018). The pretest on the students' TOEFL listening test was performed to determine the listening proficiency levels of the students. Upon the pretest, the participants were divided into five subgroups based on their proficiency level of English listening: A1, A2, B1, B2, and C1. Grouping the participants allows the teacher to set the right content differentiation for the participants based on their proficiency levels (Johnson & Christensen, 2020). A posttest was performed after the treatments were given to the participants based on their subgroups. The results of the post-test were used to measure the improvement in the listening scores.

The qualitative data of this research were obtained from the learning journal document and focus group discussions. The participants were assigned to keep track of their daily practice in the learning journal. Journaling helps students observe themselves more clearly, thus making intentional changes in their learning processes (Moon, 2006; Casanave, 2011). In this study, journaling helps both students and teachers to keep track of the students' progress during the implementation of differentiated instruction using the application. The participants were required to complete 15 practices from the application. Upon taking the practice test, they must record their scores in the learning journal provided by the teacher on a Google Sheet. The second data was collected through focus group discussions. Focus groups generate rich, detailed data through interaction among participants, where they can build on each other's ideas, clarify their opinions, and express shared or contrasting experiences (Krueger & Casey, 2015). Through focus group discussion, the researcher explored the way the participants access the content differentiation in the application. The focus group discussion in this research was conducted once with a direct meeting and recorded for further analysis. The information obtained from the focus group discussion was used to answer the second research question on how the differentiated instruction in "English Listening Step-by-Step" allocation was implemented.

Data Analysis

This research employed a paired sample t-test for the quantitative data and content analysis for qualitative data. Paired sample t-test is used as this research aimed to examine the effectiveness of the differentiated instruction in the English Listening Step by Step application to improve TOEFL listening scores. A paired sample t-test compared the means of the pretest and post-test scores of the participants (Creswell & Plano Clark, 2018). The researcher performed a normality test on the pretest and post-test results to ensure the data were normally distributed before proceeding with the paired sample t-test. The result of the paired sample t-test determined the effectiveness of the differentiated instruction approach in this study by examining the mean difference between pre- and post-test results.

The qualitative data from the students' learning journal and the focus group discussion are analyzed using content analysis. Content analysis is employed to find information on how the students access formative assessment, tiered assignment, and tiered materials from the results of the focus group discussion. It is essential to find specific content of the focus group discussion in a way that enables the researcher to interpret the two different types of data of FDG and learning journal to answer the second research question on how differentiated instruction is implemented in this research (Nowell et al., 2017). The records of students' scores

were confirmed and supported by the focus group discussion. The audio recording was coded based on students' activities in accessing formative assessments, tiered materials, and tiered assignments. Together with the students' journal, the information from the focus group discussion was triangulated and interpreted.

Findings and Discussion

This study is intended to find the effectiveness of differentiated instruction using the English Listening Step by Step application in improving TOEFL listening scores of senior high school students and how the differentiated instruction using the application was implemented. The results are discussed in two sections to cover the research questions.

The effect of Differentiated Instruction on students' listening proficiency level

The researcher began the study by conducting a pre-test on the participants. The pre-test was conducted to determine the participants' level of proficiency. The test results are important for the baseline scores to determine the differentiated content and process for each participant based on their listening proficiency levels. Below are the results of the pretest and post-test that have been conducted on the participants.

Table 1. Pretest and Posttest Results of TOEFL Listening Scores

Participants	Pre-test	TOEFL Score	CEFR Level	Post-Test	TOEFL Score	CEFR Level
P1	50	68	C1	50	68	C1
P2	49	67	C1	50	68	C1
P3	44	61	B2	46	63	B2
P4	44	61	B2	45	62	B2
P5	42	59	B2	48	66	C1
P6	40	57	B2	43	60	B2
P7	39	57	B2	48	66	C1
P8	37	55	B2	42	59	B2
P9	37	55	B2	35	54	B2
P10	34	53	B1	36	54	B2
P11	32	52	B1	35	54	B2
P12	32	52	B1	36	54	B2
P13	29	50	B1	42	59	B2
P14	27	49	B1	33	52	B1
P15	26	48	B1	38	56	B2
P16	26	48	B1	31	51	B1
P17	24	47	B1	25	48	B1
P18	23	47	B1	26	48	B1
P19	22	46	A2	29	50	B1
P20	21	45	A2	28	49	B1
P21	20	45	A2	29	50	B1
P22	19	44	A2	26	48	B1
P23	18	43	A2	23	47	B1
P24	18	43	A2	31	51	B1

P25	17	42	A2	24	47	B1
P26	16	41	A2	24	47	B1
P27	16	41	A2	20	45	A2
P28	10	33	A1	18	43	A2
P29	10	33	A1	17	42	A2

Table 1 above shows the results of the pretest and post-test performed on the participants. The table shows that there are 29 participants who joined the study. The pretest scores were converted into the TOEFL listening scores using the standardized score converter of the Educational Testing Service. Based on the TOEFL scores of the pretest, the participants were categorized into five levels of CEFR. There were 2 participants of A1 level, 9 participants of A2 level, 9 participants of B1 level, 7 participants of B2 level, and 2 participants of C1 level. Upon receiving the treatments, a post-test was conducted to see the result of the intervention.

The results show improvement in the participants' listening proficiency levels. Detailed results improvement of the participants' proficiency levels can be seen in Table 2 below.

Table 2. TOEFL Listening Proficiency Improvement

CEFR Levels	Pretest	Posttest
A1	2	0
A2	9	3
B1	9	12
B2	7	10
C1	2	4

Table 2 shows the improvement of the participants' proficiency levels. Participants with an A1 level have improved to the A2 level. There are 8 participants whose listening proficiency levels were in A2 have improved to B1 level, 5 participants initially were in B1 level have improved to B2 level upon the treatment, and 2 of the B2 level participants have improved to C1 level. The overall results of the participants' TOEFL listening scores have improved after the treatment. However, to explore the effectiveness of the differentiated approach, a Paired sample T-Test analysis using SPSS needs to be performed.

Paired sample T-Test is used in this study to explore the effectiveness of the approach used in this study. The first step performed by the researcher was conducting a normality test to examine the normality of the data. The result of the normality test using SPSS can be seen in Table 3 below.

Table 3. Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.099	29	.200*	.957	29	.276
Posttest	.107	29	.200*	.955	29	.246

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

As can be seen in Table 3 above, the result of the normality test on the pretest scores is 0,276, while the result of the normality test on the post-test scores is 0,246. Those results are greater than 0,05, which means that both pretest and post-test scores are normally distributed. Thus, the analysis using a paired T-test can be continued.

The next analysis is performed to examine the mean scores of the pretest and post-test using paired sample statistics. The result of the paired sample statistics test using SPSS can be seen in Table 4 below.

Table 4. Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	56.69	29	22.874	4.248
	Posttest	67.52	29	19.869	3.689

Table 4 above shows the results of paired sample statistics on both pretest and post-test scores. The results show that the mean of the pretest is 56,69 while the post-test mean is 67,52. The number of participants joining the study is 29 students, with a standard deviation of pretest is 22.874, and post-test is 19.869, while the standard error of mean is 4.248 for the pretest and 3.689 for the post-test. Since the pretest mean is 56.69 smaller than the post-test mean ($56.69 < 67.52$), it shows that the difference in mean between pretest and posttest is visible.

The analysis proceeds with the paired sample t-test to see the effectiveness of the differentiated instruction approach in improving TOEFL Listening scores. The result of the Paired Sample T-Test can be seen in Table 5 below.

Table 5. Paired Sample T-test result.

Paired Samples Test									
		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	pretest - posttest	-10.828	7.588	1.409	-13.714	-7.941	-7.684	28	<.001

Table 5 above shows the results of the Paired Sample T-Test of the study. The results show that the difference in mean between pretest and post-test is -10.828 with a significant value of 0,001, which is lower than 0.05. The result means that there is a significant effect of the differentiation approach on the participants' TOEFL listening scores. Since the results clearly indicate a positive effect of the differentiated instruction approach on the participants' TOEFL listening scores, it is essential to explore the implementation of the approach in the classroom

The results show that differentiated instruction is effective in improving TOEFL listening scores of senior high school students. The participants' listening proficiency increased after practicing using the "English Listening Step-by-Step" Application. This result is in line with a study performed by Kupchyk and Litvinchuk (2020) in Ukraine, which stated that differentiated instruction helps in improving the English proficiency levels of non-English university students. This study confirmed that by implementing content differentiations, students gained positive outcomes in their learning of English as a foreign language. It is also confirmed by a study performed in Ethiopia on the use of differentiated instruction in English as a Foreign Language class (Melka & Jatta, 2022), which stated that differentiated instruction is effective in improving the high school students' performance in the post-test.

The results of this study confirmed that tiered content that suits the learners' proficiency levels and readiness could indeed enhance the results of their learning proven by the increase in their TOEFL scores. This finding is supported by a study performed by Mehany (2022), which studied the writing performance of high school students in Egypt which arguing that materials differentiation helps students to progress at their best. The findings of this study strengthened the findings of a study performed by Palonga and Atompag (2023), who conducted their research on primary teachers and students in the Philippines. They argued that the implementation of differentiated instruction could enhance students' engagement in learning, which eventually improves their listening comprehension.

The findings of this study also confirmed that content differentiation through the use of technology could help learners optimize their learning and achieve better results. A study conducted by Yavuz (2021) in Turkey confirmed this finding by arguing that differentiation in the online classroom is more engaging and helps learners to study better. This is also confirmed by a study performed by Johler and Krumsvik (2024), who conducted the study in Norway. They stated that differentiation in technologically rich classrooms could enhance students' learning, performance, and achievement. Another study, which strengthened this finding, was performed by Ayuningtyas et al. (2023), who performed a literature review on the use of differentiated instruction in online classrooms. They confirmed that differentiation of content in online classrooms provided many benefits for students' listening skills, as technology could enhance the effectiveness of differentiated instruction.

The implementation of Differentiated Instruction using the "English Listening Step-by-Step" Application

This study employs a differentiated instruction approach to improve TOEFL listening scores. It is important to explore how differentiation is implemented in the classroom. To answer this question, data from documents of the participants' learning journals and focus group discussions were used. The daily practice journal was used to track the students' practice using the English Listening Step-by-Step application. The focus group discussion was used to explore the way students use the application in distance learning.

The procedure of applying the differentiated instruction in this study began by conducting the pretest to determine the students' listening proficiency levels. The pretest questions were taken from the Official Guide to the TOEFL ITP Test

from the Educational Testing Service (ETS). Based on the result of the pretest, students were grouped into 5 groups according to their proficiency level as can be seen in Table 6 below.

Table 6. Students' Listening Proficiency Levels

CEFR Levels	Students
A1	2
A2	9
B1	9
B2	7
C1	2

Based on Table 6 above, five groups are based on proficiency levels from A1 to C1. This grouping determined the tiered materials that were given to the students. This grouping also determined the differentiated assessment and assignments given to the students. The second analysis seeks information about the way differentiated instruction was implemented in a distance classroom. While this study incorporated the use of technology, it is important to examine the formative assessment, tiered process, and tiered assignment.

Participants were assigned to install the English Listening step-by-step application on their smartphones. The application provides different practices with various topics for each proficiency level, which is a form of tiered materials. The A1 level participants were assigned to do the practice at the beginner level from the application. The A2 level participants were assigned to do the practice at the A level, B1 level participants must do the practice in B1 level, B2 level participants must do the practice in B2 level, and C1 level participants must do the practice in C1 level to the application. Since there are only 15 practices in the beginner level, participants of A2, B1, B2, and C1 must also do at least 15 practices. Since the classes were conducted online, participants were assigned to record their practice scores in Google Sheets daily for 15 days. The results of their daily practices can be seen in Table 7 below.

Table 7. Learning Journal of the Participants' Daily Practice Scores

Participant	Daily Practice Tracking Journal														
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15
P1	4/4	4/4	4/4	6/6	6/6	5/5	4/4	4/4	6/6	7/7	4/4	4/4	5/5	6/6	4/4
P2	4/4	4/4	6/6	4/4	6/6	4/4	5/5	6/6	5/5	4/4	6/6	6/6	6/6	5/5	6/6
P3	4/4	5/5	5/5	5/5	5/5	5/5	4/4	4/4	4/4	5/5	4/4	4/4	4/4	7/8	4/4
P4	5/6	4/4	5/5	6/6	4/4	4/4	4/4	4/4	4/5	3/4	7/8	6/6	4/5	4/4	5/5
P5	4/4	5/5	5/5	5/5	5/5	5/5	4/4	4/4	4/4	5/5	4/4	4/4	4/4	4/4	4/4
P6	4/4	5/5	5/5	5/5	5/5	5/5	3/4	4/4	5/5	4/4	4/5	6/6	4/4	4/5	4/4
P7	5/5	5/5	5/5	5/5	4/4	5/5	5/5	4/4	5/5	4/4	4/4	3/3	4/4	5/5	4/4
P8	4/5	3/4	5/5	4/5	4/4	4/4	2/4	5/5	3/5	4/4	4/4	3/4	3/4	3/4	4/4
P9	5/5	4/4	4/4	5/5	4/5	4/4	5/6	5/5	7/7	6/6	6/6	4/4	5/5	4/4	6/6

P10	5/5	5/5	4/4	5/5	5/5	6/6	4/5	5/5	5/6	6/6	6/7	4/4	5/5	4/4	4/4
P11	3/4	4/4	3/4	4/4	2/4	5/5	4/4	3/4	3/4	4/4	7/7	4/4	4/5	4/4	4/4
P12	5/5	4/4	4/4	5/5	5/5	4/5	7/7	5/6	5/5	6/6	4/4	4/4	5/5	4/4	4/4
P13	4/4	4/4	4/4	3/3	5/5	3/4	3/3	1/1	3/3	3/3	4/4	2/2	3/4	4/4	2/2
P14	4/4	4/4	4/4	3/3	5/5	4/4	3/3	3/3	3/3	3/3	4/4	3/4	4/4	4/4	4/4
P15	3/4	3/4	3/3	4/4	3/4	3/3	3/3	2/3	3/4	2/2	4/4	3/4	4/4	5/5	3/5
P16	4/4	4/4	4/4	3/3	4/4	3/3	1/1	3/3	4/4	2/2	2/2	4/4	4/4	2/2	4/4
P17	4/4	4/4	4/4	3/3	4/4	3/3	1/1	3/3	4/4	2/2	2/2	4/4	4/4	2/2	4/4
P18	3/4	4/4	2/4	3/3	4/4	2/3	1/1	3/3	1/3	3/4	2/2	2/4	4/4	2/2	4/4
P19	4/4	4/4	3/3	4/4	3/3	1/1	3/3	3/3	4/4	2/2	4/4	2/2	4/4	5/5	2/2
P20	3/3	4/4	4/3	3/3	2/2	4/4	3/3	3/3	2/2	3/3	2/2	3/3	4/4	2/2	3/3
P21	4/4	3/4	3/3	4/4	3/3	1/1	3/3	3/3	4/4	2/2	4/4	2/2	3/4	5/5	2/2
P22	3/4	4/4	3/3	4/4	3/3	1/1	3/3	3/3	4/4	2/2	4/4	2/2	4/4	5/5	2/2
P23	4/4	4/4	3/3	4/4	3/3	1/1	3/3	3/3	3/4	2/2	4/4	2/2	3/4	5/5	2/2
P24	3/4	4/4	2/3	3/4	3/3	1/1	3/3	3/3	4/4	2/2	4/4	2/2	4/4	5/5	2/2
P25	3/4	4/4	3/3	4/4	3/3	1/1	3/3	3/3	4/4	2/2	4/4	2/2	4/4	5/5	2/2
P26	3/4	4/4	5/5	3/3	2/2	3/3	4/4	3/3	2/2	3/4	3/3	3/3	3/4	3/3	4/4
P27	4/4	4/4	3/3	4/4	3/3	1/1	3/3	3/3	4/4	2/2	3/4	2/2	3/4	5/5	2/2
P28	3/4	3/4	3/3	4/4	3/3	1/1	3/3	3/3	4/4	2/2	4/4	1/2	3/4	4/5	2/2
P29	3/4	3/4	2/3	4/4	2/3	1/1	3/3	3/3	3/4	2/2	4/4	2/2	2/4	4/5	2/2

Table 7 shows participants' daily practice scores. The table shows that the participants have taken 15 practices with one practice each day. They recorded their scores in a Google Sheet, which can be tracked by the teacher. The table shows that all 29 participants had completed the practices before they were given the post-test. The scores show different marks as each participant took different practice levels according to their proficiency groups. This shows the flexible grouping and tiered assignments implemented in this research. The practices done by the participants serve as formative assessments to monitor the participants' progress. To support this result, a focus group discussion involving all students was conducted.

Content analysis was conducted on the results of the focus group discussion to examine how technology is utilized to access tiered assignments, formative assessment, and tiered materials by the participants. The analysis result of the focus group discussion can be seen in Table 8 below.

Table 8. Focus Group Discussion Summary

Questions	Answers
How long have you known the English Listening Step-by-Step application?	• 1-5 months (29 participants) • 6-11 months (-) • More than a year (-)
How many times do you use the application for practice daily?	• 1 time (16 participants) • 1-3 times (9 participants) • More than 3 times (4 Participants)
When do you use the application for practice daily?	• After the teacher informed me to submit my score (9 participants)

	• After class, before going home (13 participants) • At night, when I study (5 participants) • Anytime I remember it (2 participants)
How many practice sets did you do every day?	• 1 practice set (21 participants) • More than 1 practice set (8 participants)
Why did you do only 1 practice? (additional question for those who did 1 practice each day)	• Because we have other homework to do from other subjects (9 participants) • Because the teacher only asked us to do one practice each day (11 participants)
Why did you do more than 1 practice each day?	• Because it is interesting, and I just want to continue practicing (5 participants) • Because I the questions are only 4 to 6 questions. So I want to practice more (4 participants)
How long did you take to do one practice?	• Less than 5 minutes (12 participants) • 5-10 minutes (13 participants) • More than 10 minutes (4 participants)
Did you use the transcription feature of the application?	• Yes (18 participants) • No (11 participants)
When did you use the transcription feature? (additional question for those who answered “yes” to the previous question)	• When my answer is wrong then I click the transcript to understand the audio (12 participants) • When I want to confirm my answer (5 participants) • After I listen to the audio. It helped me to understand the question (1 participant)
Did you retake the practice test when your answers were incorrect?	• Yes (23 participants) • No (6 participants)
Did you continue using the application after 15 practices?	• Yes (28 participants) • No (1 participant)

Table 8 above shows the summary of the focus group discussions. The data shows that students accessed the tiered materials differently according to their most convenient times. The data shows that more than half of them accessed the practice test once a day, while the rest mentioned accessing the practice more than once. Nine students mentioned that they accessed it after the teacher informed them, while the rest mentioned that they accessed it after school or during night study. The data mentioned that 21 students took one practice test each day, while the rest did more than one practice test each day. These results show variation in the way students accessed the tiered assignment provided by the application.

In relation to the tiered assignments, these assignments also serve as formative assessments, which show students' progress during the use of tiered materials in the application. Various ways of accessing the tiered materials provided by the application were shown in the focus group discussion data. Thirteen students took around 5-10 minutes to complete one practice test; twelve of them took less than 5 minutes to complete one test, while the rest needed more than 10 minutes to complete one test. Some students used the transcription feature to help them understand the materials and perform better in their practice test, while others used the transcription feature to confirm their answer and their understanding. The results show variation in their learning process that helps them learn better.

The finding of this research indicates that a differentiated instruction approach could greatly impact EFL students' listening proficiency when it is well planned and carefully implemented. The findings show that the teacher used flexible grouping and tiered assignments in the implementation of differentiated instructions in this study, which promote improvement of students' listening proficiency levels. This finding supported a study conducted by Wong and Chan (2022), which was performed in tertiary education in Hong Kong. The result confirmed that well-designed content and flexible grouping helped learners to achieve better results in their studies. This result is strengthened by Purwaningwulan (2024) in the study conducted in an EFL speaking class in Indonesia, which highlighted the importance of tiered assignments to significantly improve the students' speaking proficiency. A study conducted by Mohamed et al., (2025) in Ethiopian schools, which highlighted that teachers' decisions in using tiered assignments played a crucial role in students' achievement in the EFL classroom, has also supported this finding.

Another finding from this study is the flexibility of accessing the learning materials and formative assessments that played important roles in the success of the students in improving their TOEFL listening scores. The result shows that the students have the authority on how and when they should access the formative assessments provided by the application. This tiered process helped them progress at their best and eventually performed better on the TOEFL test. This is supported by the findings of a study performed in Germany, which argued that the tailored content and process that allow flexible access to the materials in differentiated instruction could enhance the students' achievement in EFL classrooms (Pozas et al., 2022). It is also confirmed by a study conducted by Belyaeva (2023), which was conducted in Russia, that highlighted the effectiveness of a tiered process to enhance the students' performance in EFL classrooms of non-language students. Another study, which confirmed this finding, was performed by Zuaro (2023) in Italy, which stated that process differentiation is widely adopted to enhance students' performance and improve language skills. A study performed by Widayanti et al. (2024) in Indonesia confirmed this finding by highlighting the effectiveness of process differentiation in improving students' engagement in the EFL classroom. This study confirmed the improvement of learning outcomes using process differentiation. Goyibova et al. (2025), in their study on the use of process differentiation in Uzbekistan, argued that the tiered process and flexible ways of accessing the learning materials helped students to improve their achievement in learning. Thus, the tailored process and flexibility of accessing the learning

materials in the “English listening step-by-step” application helped students in improving their TOEFL listening scores and their proficiency level.

Conclusion

This study examines the implementation of differentiated instruction in the “English Listening Step-by-Step” application in improving TOEFL listening scores of senior high school students. The results indicate that differentiated instruction in the application has significantly improved the participants’ TOEFL Listening scores. This has been proven by the improvement of students’ TOEFL listening scores based on the results of pretest and post-test. Not only does it improve the participants’ TOEFL listening scores, but also their listening proficiency level. More than 50% of the students have improved their proficiency level after the implementation of differentiated instruction using tiered content in the “English Listening Step-by-Step” application.

This is made possible by the regular practice and the well-designed differentiated instruction. Despite the distance learning, students were able to fully and flexibly access the tiered contents, which include tiered assignments, formative assessments, and tiered materials to help them practice their listening skills. The grouping helped them in selecting the right and suitable materials and practice tests for their levels. In conclusion, differentiated content instruction provided by the “English listening step-by-step” application, together with the teacher’s and participants’ careful implementation of differentiated process instruction, could greatly enhance the participants’ TOEFL listening scores. However, since this study was conducted in a distance classroom, the teacher could not intently monitor the students’ process and could not address students’ challenges during the implementation of the approach. Further study should be done in a face-to-face classroom so that the teachers can directly address the challenges and monitor the students’ progress.

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INTEGRATION OF LOCAL AGROINDUSTRY IN ETHNOSCIENCE-BASED CHEMISTRY TEACHING: A STRATEGY TO STRENGTHEN ECOLOGICAL LITERACY AND ENTREPRENEURIAL STUDENT CHARACTERS

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Received: 20 October 2025; Accepted: 18 November 2025

Abstract

This study aims to develop and evaluate an ethnoscience-based chemistry teaching module supported by local agroindustry resources in West Sulawesi as a strategy to strengthen students' ecological literacy and entrepreneurial character. The research employed a research and development (R&D) approach using the 4D model. Data were collected from 36 science teachers through questionnaires assessing the feasibility, relevance, and applicability of the developed module. The results indicated that teachers' responses were very positive, particularly in terms of contextual integration of agroindustry practices, promotion of ecological awareness, and potential to foster entrepreneurial attitudes among students. The findings suggest that integrating local agroindustry within ethnoscience-oriented chemistry learning provides meaningful contextualization, enhances students' understanding of the relationship between science and local wisdom, and encourages sustainable entrepreneurial values. This innovation has the potential to contribute to both ecological preservation and the development of future-oriented competencies in education.

Keywords: agroindustry, chemistry teaching, ecological literacy, entrepreneurship, ethnoscience

Introduction

Science education has undergone a significant paradigm shift, moving away from traditional, content-centric methods toward holistic, contextual, and sustainable pedagogical frameworks (DeBoer, 2019). Contextual learning, which grounds instruction in environmental phenomena and local conditions (Dewi & Primayana, 2019), is particularly suited to the Natural Sciences. This approach enables students to explore natural potential, identify problems, and devise solutions to environmental issues (Haryanto & Arty, 2019), simultaneously fostering character development (Miller, 2021).

A prominent application of the contextual approach in science is through ethnoscience, defined as a community's system of scientific knowledge (Mukti et al., 2022) that synthesizes the role of local wisdom within sustainable education (Lestari & Suyanto, 2024). This transformation emphasizes integrating local wisdom (ethnoscience) with socio-scientific reasoning via field-based learning (Kinslow et al., 2019). Ethnoscience encompasses diverse elements of local heritage—including traditions, ceremonies, arts, unwritten rules, and sustainable



resource management knowledge (Ilhami et al., 2019). Its integration into science curricula not only aids in preserving this cultural knowledge (Ilhami et al., 2021) but also effectively cultivates environmental awareness (Muizz & Prahani, 2023), discipline, honesty, responsibility, and social concern (Hidayati et al., 2020).

Pedagogically, ethnoscience-based learning guides students through a structured process of understanding environmental problems, planning and implementing solutions, and reflecting on outcomes (Zaki et al., 2024). When combined with Problem-Based Learning (PBL), it proves highly effective in developing higher-order thinking skills (Sarkingobir & Bello, 2024). This synergy exemplifies the revitalization of local wisdom within modern education for character building (Sakti et al., 2024; Sari et al., 2023). Successful implementation requires a systemic commitment from stakeholders to create a learning ecosystem that advances cognitive intelligence (Wahyuni & Fawaida, 2024), preserves cultural heritage, and develops the environmental literacy necessary to address complex socio-scientific issues (Ristanti & Irawan, 2025).

Furthermore, ethnoscience-based learning enhances students' understanding of human-environment interconnections, promoting wise stewardship (Widiyawati et al., 2025), while also fostering innovation, self-reliance, and the ability to identify entrepreneurial opportunities in local resources (Jardim, 2021). One such local potential is agroindustry, which involves adding value to raw agricultural commodities through processing (Faqih et al., 2020). Reflecting the interplay between agriculture, technology, economics, and environment (Suwandi et al., 2022), agroindustry prioritizes eco-friendly processing, waste reduction, and by-product utilization (Aguilar-Rivera, 2019), as seen in West Sulawesi's cocoa, coffee, and coconut oil industries (Chakti et al., 2024).

A review of the literature confirms that while ethnoscience-based learning has been extensively developed and proven to enhance the relevance of science education, most studies focus on culture and local wisdom in a general sense. Research specifically addressing local agroindustrial practices as a learning resource that integrates ecological literacy and entrepreneurial attitudes remains underexplored.

Ecological Literacy (Ecoliteracy) constitutes a fundamental understanding of ecosystem principles and their application in building sustainable human societies (Häggström & Schmidt, 2020). It advocates for natural resource management based on regeneration and carrying capacity, rather than over-exploitation (Harefa et al., 2023), and cultivates a critical 21st-century mindset for analyzing problems from multiple perspectives to devise innovative, sustainable solutions (Kurniawan et al., 2019). The aspects of ecological literacy utilized in this teaching module are understanding local ecological concepts, environmental awareness, pro-environmental attitudes, and decision-making (Widiyawati et al., 2025).

An entrepreneurial attitude encompasses the character, mindset, and behaviors that drive individuals to create, manage, and develop ventures courageously and innovatively, while being prepared to undertake calculated risks (De Pablo Valenciano et al., 2019). This includes the capacity to envision future opportunities and maintain a strategic vision that guides action (Diaz-Sarachaga & Ariza-Montes, 2022). Its key dimensions are creativity and innovation, independence, perseverance and responsibility, collaboration and communication,

and social awareness with an understanding of economic value (Nurbayani et al., 2023).

Method

The methodological framework for this research is based on the Research and Development (R&D) approach, specifically the 4-D model (*Define, Design, Develop, Disseminate*) as outlined by Thiagarajan et al. (1974). The sequential stages of this process are delineated in Figure 1.

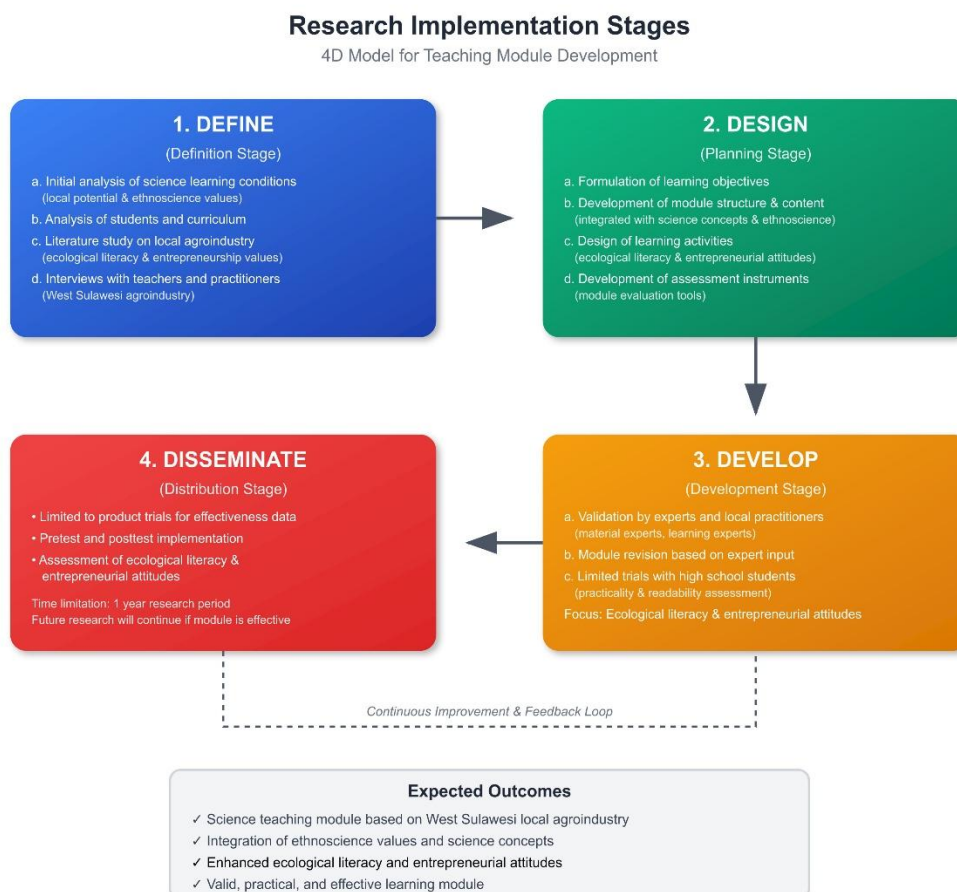


Figure 1. Stages of 4D Model Implementation

This section outlines the systematic approach taken to develop the teaching module and collect evaluative data. Development Approach and Model. This study adopted a Research and Development (R&D) approach, chosen for its suitability in creating a specific educational product—in this case, an ethnoscience-based chemistry module. The development process followed the 4D model, which comprises four distinct stages: 1) **Define**. This initial stage focused on needs analysis and establishing a foundation for the module; 2) **Design**. Based on the definition stage, a preliminary module draft was created; 3) **Develop**. In this stage, the draft was refined into a viable product through Expert Validation, Revision, and Limited Trial: The revised module was then tested with 36 science teachers as the primary end-users. 4) **Disseminate**. As the final stage, this phase involves sharing the validated product.

Subjects and Data Collection

Research Subjects: The participants for the product trial were 36 science teachers from various schools across West Sulawesi. Selecting teachers as subjects is highly appropriate, as they possess an in-depth understanding of the learning context and can accurately assess the module's practicality for classroom use. **Data Collection Instrument:** The primary data collection tool was a questionnaire. This instrument was designed to evaluate Feasibility, relevance, and applicability, regarding the ease of implementing the module in actual school learning environments.

Findings and Discussion

Findings

This data comes from a questionnaire administered to 36 teachers to assess the feasibility, relevance, and applicability of an ethnoscience-based chemistry teaching module that integrates local agroindustry. The 20 questions (indicated by numbers 1-20) likely cover various aspects such as content accuracy, cultural relevance, ease of use, learning effectiveness, and alignment with curriculum goals. The scoring uses a 5-point Likert scale, where a higher score indicates stronger agreement or a more positive assessment. The findings are derived from a descriptive analysis of the total scores and the average scores for each question.

Overall Teacher Acceptance

The total scores for the 36 teachers range from a low of **69** to a perfect high of **100**. The average total score across all respondents is **93.4**, which is very high (93.4% of the maximum possible score). This indicates a strongly positive overall perception of the module.

Categorization of Respondent Perceptions

To better understand the distribution, we can categorize the total scores:

Table 1. Distribution of Respondent Perceptions

Category	Score Range	Number of Teachers	Percentage
Very High	96 - 100	17	47.2%
High	86 - 95	12	33.3%
Moderate	76 - 85	5	13.9%
Low	≤ 75	2	5.6%

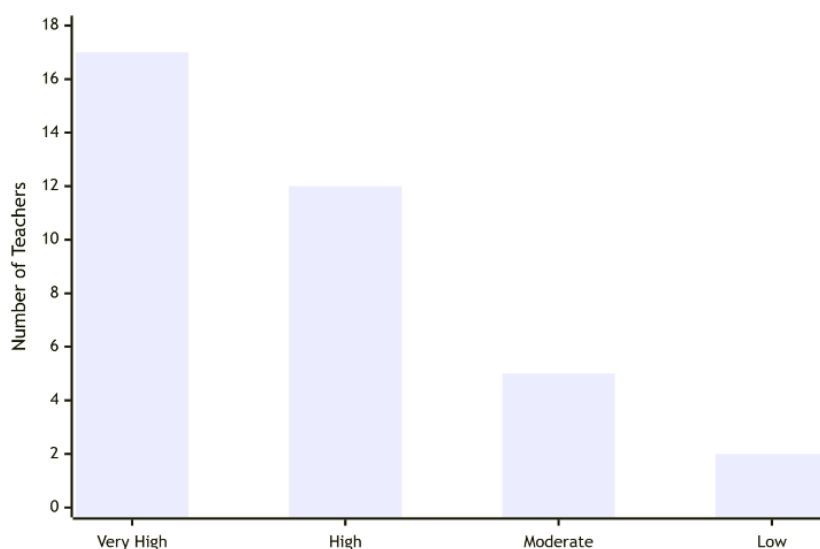


Figure 2. Distribution of Teacher Acceptance Scores

This bar chart shows the number of teachers in each performance category, clearly illustrating that the majority (80.5%) are in the "High" to "Very High" categories.

Performance by Question Item

The average score for each of the 20 questions was calculated to identify the strongest and weakest aspects of the module.

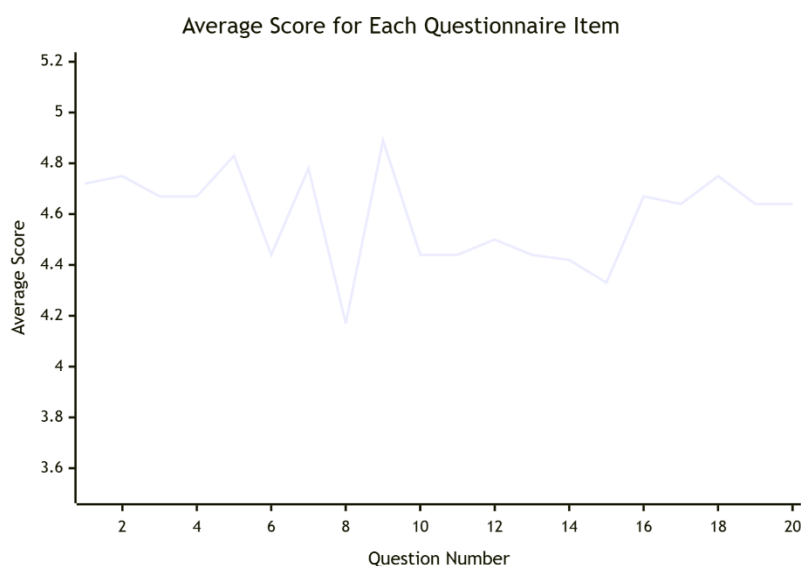


Figure 3. Average Score for Each Questionnaire Item

This chart visualizes the average score for each question, making it easy to see which items received the highest and lowest ratings. From the data, we can identify the key strengths and weaknesses as follows.

1. **Strongest Items** (Highest Average Score, ~4.8-4.9):
 - Question 9: Likely related to the clarity of instructions or the systematic organization of the module.
 - Question 5: Possibly concerning the relevance of the content to the chemistry curriculum.
2. **Weakest Items** (Lowest Average Score, ~4.1-4.2):
 - Question 8: Most likely pertains to the availability and ease of obtaining the local agroindustrial materials required for the activities.
 - Question 15 & 14: Could be related to the time required to implement the module or the assessment techniques provided.

Discussion

The data provides robust evidence for discussing the three core aspects: Feasibility, Relevance, and Applicability.

Feasibility

Question 8 received the lowest average score (4.17), indicating a clear concern. However, the overall feasibility is still rated highly, as most other questions scored well above 4.4. The primary challenge for feasibility lies in the practical logistics of integrating the local agroindustry. Teachers may be concerned about the cost, effort, or seasonal availability of the required local materials. This does not mean the module is unfeasible, but it highlights a critical area for support. To enhance feasibility, the module should be supplemented with a guide that includes a list of alternatives, easily sourced local materials and strategies for community engagement to secure resources.

Relevance

Questions related to relevance (e.g., Q5: 4.83) are among the highest-rated. Teachers overwhelmingly agree that the module connects chemistry to real-life contexts. The high scores in this area confirm that the ethnoscience approach is highly effective in establishing relevance. By rooting chemical concepts in local agroindustrial practices (e.g., fermentation, soil chemistry, food preservation), the module makes learning more meaningful for students. It bridges the gap between abstract textbook theory and students' cultural and economic environment, potentially increasing motivation and retention of knowledge.

Applicability

The high scores on items like Q9 (4.89) suggest the module is well-designed and easy to implement in a classroom setting. The lower scores on Q14 and Q15 suggest minor hurdles in practical execution, possibly related to time or assessment. The module demonstrates high **applicability** in terms of user-friendliness and instructional guidance. Teachers feel confident in their ability to deliver the content. The slightly lower scores on time/assessment-related items suggest that the module might be perceived as somewhat dense. Providing teachers with flexible lesson timelines and differentiated assessment strategies could further improve its applicability, allowing them to adapt it to their specific schedule and student needs.

Conclusion

In conclusion, the teaching module is highly valid, relevant, and applicable according to the majority of the 36 teachers surveyed. The integration of local agroindustry through an ethnoscience lens is recognized as a major strength that adds significant value and relevance to chemistry education. More significantly, this approach proves capable of simultaneously strengthening students' ecological literacy and fostering sustainable entrepreneurial values. By validating local knowledge through scientific principles, the module not only enhances chemistry comprehension but also cultivates cultural pride and environmental responsibility.

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TRACES OF FAITH IN THE LIVES OF YOUNG CHRISTIANS

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Received: 30 October 2025; Accepted: 18 November 2025

Abstract

Young Christians are called to follow the path of faith amidst the challenges of our time, such as digitalization, secularization, and the search for identity. In *Christus Vivit*, Pope Francis affirms that the living Christ is present with young people, guiding them to discover the true meaning of life in the light of the Gospel. Therefore, young people's path of faith needs to be nurtured so that they can bear witness to Christ's love in their daily lives. This paper was compiled using a document review method. The Apostolic Exhortation *Christus Vivit* issued by Pope Francis was the primary source evaluated. After reading and examining the document's contents, the author summarizes the key points. *Christus Vivit* affirms that young people are a vital part of the Church, called to walk the path of faith joyfully amidst the challenges of the modern age. This document serves as a relevant guide for young Christians to draw closer to the living Christ. Therefore, it is important for young people to internalize this message through active involvement in the life of the Church, while families and pastoral care providers are expected to support their continued growth in faith.

Keywords: *Christus Vivit*, Church, faith, spirituality, young Christians

Introduction

The rapid changes experienced by young Christians are marked by advancements in digital technology, secularization, and the struggle for identity. In situations like this, many young people face difficulties in maintaining their beliefs in a world that often prioritizes success, popularity, and personal freedom. This aligns with the journal article on the Role of the Church in the Development of Christian Education for Young People in the Digital Technology Era (Dalensang & Molle, 2021). In the encyclical *Christus Vivit*, Pope Francis stated that Christ is not a figure of the past; rather, He is a Person who is alive and present in every step of young people's lives. "Christ lives, and He wants you to live!" is the title of his writing (CV 1). The Church has once again realized that every young person has an important place in God's plan of love and is called to have a personal encounter with the living Christ through this call.

In addition, Pope Francis stated that the Church should not distance itself from the world of young people; rather, the Church must walk with them, listen to them, accompany them, and nurture their faith in the realities of the times (CV 37). *Christus Vivit* encourages young people to find true meaning in life in the Gospel and use their faith to witness and serve others (CV 174). To be witnesses of Christ's



love in daily life, young Christians are asked to maintain and follow in the footsteps of their faith. Therefore, the purpose of this encyclical review of *Christus Vivit* is to study Pope Francis' message and teachings on the role of young people in the Church and the world. Through this thinking, it is hoped that young Christians will become increasingly aware that faith is not only inherited but must be lived and manifested in every aspect of their lives, including at school, in their families, in their communities, and in the digital world where they interact every day.

Method

This research uses qualitative methodology and document analysis. This method was chosen because this research is reflective and theological, aiming to explore how faith influences the lives of Christian adolescents, using official sources from the Catholic Church as a basis. The Apostolic Exhortation *Christus Vivit*, issued by Pope Francis in 2019, is the primary source for this research, which addresses faith, vocation, and the role of young people in the Church. Because this document contains many principles related to the theme "Footprints of Faith on the Path of Christian Youth's Life," it was thoroughly examined. Additionally, secondary sources such as books and journals discussing pastoral accompaniment and youth spirituality were used as supporting material for the analysis. The books and journals used were obtained from a search using the Google search engine with the keyword *Christus Vivit*. Data was collected by thoroughly reading the text of *Christus Vivit*. Then, important points related to the research subject were marked. Content analysis and thematic analysis were used to analyze the data. Content analysis was conducted by identifying, grouping, and interpreting the main themes found in the documents. To ensure data validity, source triangulation was conducted by comparing the interpretation results of *Christus Vivit* with the perspectives of academics and theologians. This research aims to identify how the message of *Christus Vivit* influences the faith lives and spiritual well-being of young Christian people today.

Findings and Discussion

The Living Christ: The Beginning of the Faith Journey of Young People

"Christ is alive, and He wants us to live!" is the powerful cry that Pope Francis made when opening *Christus Vivit* (CV 1). The entire document consists of this sentence. The faith of young people begins with their life experiences of Christ, who is alive and present in their lives, not just a set of teachings. This message reminds young people that their lives have meaning because God is with them every day in our fast-paced and stressful modern life. When a young Christian realizes that God is a friend walking with them, not just a figure from the past, their journey of faith begins. "He lives and is among us," said the Pope (no. 2). This awareness fosters a spirit of optimism and encourages children to find meaning in a world that often leaves them feeling empty. A study published in the journal *Fides et Ratio* (Refo, 2024) reinforces Pope Francis' statement in *Christus Vivit* (1–3) about Christ living and accompanying the journey of young people. This research shows that the enthusiasm of young people reflects the life of Christ in the world. The journal states that young people's faith is not merely a taught doctrine, but a personal experience with God's love, which fosters new hope and enthusiasm in today's world.

A Young Church and Becoming a Traveling Companion

In *Christus Vivit*, the Church is described as a "mother who understands, listens to, and accompanies" young people, and Pope Francis emphasizes that the Church must learn from the spirit of the younger generation because "young people can be an inspiration for the Church to continue to renew itself" (no. 37). This shows that the journey of adolescent faith requires a supportive community. The church became a place where they could develop their faith, find themselves, and experience unconditional love. The roles of teachers, spiritual companions, and fellow believers are very important in schools or communities to help young people face life's confusion and challenges with realistic and loving faith guidance. A study published in the journal *Fides et Ratio* (Refo, 2024) supports Pope Francis' message in *Christus Vivit* (nos. 37 and 243) that the Church must be a friend to young people. The journal stated that the Church must provide space for young people to participate in faith life and trust their ability to actively participate. In that research, it was explained that young people are not only recipients of pastoral guidance, but also partners who can enrich the Church with their creativity and service.

The Preparatory Document: *Young People, the Faith, and Vocational Discernment* (Shiju, 2017) also supports Pope Francis' idea in *Christus Vivit* (nos. 37 and 243) that the Church should be a companion on the journey for young people. In the Accompaniment section, it is explained that the Church must walk alongside young people, listen to their experiences, and help them find meaning in life in a dialogical and loving way. The document states that proper accompaniment does not control, but encourages with empathy and provides space for them to grow in faith. This view aligns with the spirit of *Christus Vivit*, which sees the Church as a community that ignites new hope in children's faith journeys while bearing their difficulties.

Young people, who are responsible for the future of the Church, must be actively involved in all Church activities, especially in the local Church. History shows that young people played an important and significant role in the development of the Catholic Church's faith. Young people should not be looked down upon by those who feel older, because it is the young who will continue the work and realize the hopes that the senior generation failed to achieve. The Catholic Church itself provides young people with opportunities to participate in various activities and categorical groups. As the leader of the universal Catholic Church, Pope Francis is deeply concerned about young people. Pope Francis affirms the existence of young people through the Church document titled *Christus Vivit*. This shows that young people are not just objects of pastoral care; they are an essential part of the Catholic Church. Young people can use their involvement in the life of the Church as a way for God to continue to grow the Catholic faith. As God's representatives today, young people must be able to be a source of light and salt for others in the life of the Church and society. The presence of young people brings good news for the Church and the general public, including those who have not yet known Christ. The Church should not simply let them go as they pursue their missionary calling as young people; instead, the Church should accompany and support them (Ronaldo, 2022).

Januari (2022), in his writing "Young People as the Church: A Theological Review," affirmed that young people are not only the future of the Church, but they are the Church itself, the living and dynamic body of Christ. Their faith became the

lifeblood of the Church, constantly renewed by the Holy Spirit. This idea aligns with Spadaro's (2020) thinking, who wrote that the Church remains young not because of the age of its members, but because of the Spirit that renews the Church through the faith of young people. Their presence, creativity, and involvement are a tangible sign that the Church is a living, inclusive, and missionary community. Within the context of the Indonesian Church, there are also similar opinions. Risa and Yuliati (2021) show that the participation of young people in Basic Church Communities (KBG), even through digital media, demonstrates genuine faith and strengthens the spirit of community in the modern Church. Pattinama (2022) states that the faith of young people grows through personal accompaniment based on love and life example, not just teaching. According to the call made by the Pope in *Evangelii Gaudium* (2013), the Church must be present and meet young people where they are, and proclaim the joy of the Gospel in their own cultural and digital language. This thinking aligns with this call.

Calling and Mission: Finding Direction in Life's Path

One important message from *Christus Vivit* is that God has a special calling for every young person. "God calls each of us to be something greater," said the Pope (p. 107). This calling doesn't always mean becoming a priest, monk, or nun; rather, it means being a person who lives in service and love wherever they are. Finding one's life calling during the journey of faith is an important part of the "footprints of faith." Young people are encouraged to be brave enough to listen to God's voice in silence, to discover what truly brings happiness and peace. Pope Francis emphasized that the process of understanding (spiritual discernment) is crucial to prevent young people from getting caught up in unclear decisions or being influenced by the rapidly changing digital world (nos. 278–279). So, faith serves as their moral compass as they make life decisions.

The Pope's call in *Christus Vivit* (nos. 107 and 278–279) regarding the vocation of young people aligns with the findings of a journal study written by Refo (2023), which found that young people have great potential to be agents of evangelization in society. The journal affirms that mature faith enables young people to live out the Gospel through study, work, and social service, making their lives a true testimony to the living love of Christ.

In the Preparatory Document (2017), Pope Francis's call in *Christus Vivit* (numbers 107 and 278–279) regarding the vocation of young people is further strengthened, especially in the sections on Faith and Vocation and The Gift of Discernment. It is explained that faith is not limited to the personal aspect; rather, faith encourages every young person to realize their calling in this world and demonstrate God's love through wise life choices. This document emphasizes the importance of a discerning understanding process to distinguish God's voice from the many voices of the world so that young people can respond to the call with inner freedom and spiritual maturity. This understanding reinforces the Pope's message that every young person has a specific purpose in this world, and faith helps them live a meaningful life according to God's will (Shiju, 2017).

Challenges of Faith in the Modern World

Pope Francis also honestly discussed the problems faced by young people today, such as social pressure, instant culture, and confusing information overload.

Many teenagers are exposed to deep sadness, even losing their sense of direction and purpose in life (CV 72). The journey of faith is often marked by struggles, doubts, and weariness in such circumstances. However, faith can grow stronger precisely in difficulty. *Christus Vivit* calls on the Church and young companions in this context to be truly present and not judgmental, but to listen and accompany (CV 292). To encourage young people to open up and rediscover God's presence amidst life's difficulties, an empathetic and accepting approach is key. Therefore, the challenges of the times do not extinguish our faith; on the contrary, they allow us to deepen it. The research findings published in the journal *Refo* (2023), which found that secularization and social media are the main obstacles to maintaining the faith of young people, reinforce Pope Francis' statements in *Christus Vivit* 72 and 292 about the challenges of faith in the modern world. The research results indicate that the flow of information, a materialistic lifestyle, and high social pressure are causing many young people to experience a spiritual identity crisis. As a result, the Church is called to be present with an empathetic, dialogical, and relevant pastoral approach to the digital realities faced by today's young generation.

In the Preparatory Document, the section titled "Challenges in Today's World" aligns with Pope Francis' views on the challenges of faith in the modern world. It was revealed that young people live in a "hyper-connected" world, full of information, digital distractions, and social pressures, which often causes them to lose their spiritual direction. This document emphasizes that globalization, individualism, and consumer culture lead to a weakening of faith and personal relationships with God. The Church is asked to listen, understand the realities of young people, and create spiritual spaces that relate to their digital lives in order to respond to this situation. Thus, the message of *Christus Vivit* is that young people's faith must grow through accompaniment that revives their spiritual sensitivity amidst the currents of the modern world, rather than through coercion (Shiju, 2017). (Paus, 2019)

Joy and Hope as Signs of a Living Faith

Joy always marks the end of a true journey of faith. "Christ lives and wants young people to be full of joy," Pope Francis said repeatedly (no. 1, no. 132). This feeling of joy is not just temporary satisfaction; it is a state of the heart resulting from a strong relationship with God. Young people are brave enough to love, serve, and spread hope in their communities because of their living faith. Hope is the result of sincere belief. The Pope says that children are "God's present," not just the future, in *Christus Vivit* (number 299). From this moment on, this statement invites all young people to realize that they have a significant role in changing the world. Therefore, the footprints of faith are a call to show God's love in the world, not just a personal journey.

Through *Christus Vivit* (numbers 132 and 299), Pope Francis says that true faith must bring happiness and hope. This aligns with *Refo*'s (2023) research, which states that young people are crucial in presenting a joyful, solidary, and loving face of the Church. The study shows that the faith of young people continues to bring renewal and enthusiasm to the Church community today, despite facing various challenges.

Through the Preparatory Document, especially in the section titled "Walking with Young People," Pope Francis's hope in *Christus Vivit* (numbers 132 and 299)

that young people live with a free spirit and joy is evident. It is mentioned there that the Church is called to be a witness of hope in the fragility of the young world, but not with harsh words, but with the testimony of genuine love. This document shows that living faith always leads to happiness, and young people who are brave enough to open themselves to God will find true happiness that does not depend on external events. This thinking deepens the meaning of *Christus Vivit*, which means that the living Christ inspires young generations to be bearers of hope in society and not give in to the darkness of the times (Shiju, 2017).

Overall, the content of *Christus Vivit* shows that the faith journey of young Christians is not a smooth path, but rather a journey filled with process and growth. Every young person is called by the living God to find meaning in His love. They are asked to join the Church that supports them and to bravely answer their life's calling with a spirit of service and hope. Through this document, Pope Francis invites the entire Church to trust young people and accompany them with love, so that their faith not only endures, but also becomes a source of true joy in their lives.

Based on information from available sources regarding the challenges facing young Christians (digitalization, secularization, and instant culture) and pastoral guidance from *Christus Vivit* (CV), the following is a proposed measurable and implementable pastoral program focused on digital accompaniment and strengthening spiritual identity. This plan is based on Pope Francis's call for the Church to walk with young people, listening to, accompanying, and nurturing their faith in the realities of the times, while remaining empathetic, dialogical, and relevant to the digital reality.

Youth Pastoral Program Design: Traces of Faith in the Digital Space

Main Goal: Helping young people discover the living and present Christ, making faith a moral compass amidst the challenges of secularization, individualism, instant culture, and the burden of digital information.

Specific Challenges Addressed (Contextualization)

This program specifically addresses:

1. **Secularization and Individualism:** The modern world often prioritizes success, popularity, and personal freedom, which can lead to a weakening of faith and a personal relationship with God.
2. **Instant Culture and Information Overload:** Social pressure and a confusing overload of information can cause young people to lose their way, experience deep sadness, and lose their spiritual sensitivity.
3. **Hyper-Connected World:** The need for mentoring that helps young people develop spiritual discernment to avoid being swept away by unclear decisions or the influence of a rapidly changing digital world.

Scalable Digital Mentoring Model

The mentoring model must be empathetic, accepting, and non-judgmental, as well as creating a spiritual space that is relevant to their digital lives.

Table 1. Program Pillar: Digital Faith Literacy

Program Components	Implementation Description (Activity Tools)	Link to Challenge
Content Moderation & Spiritual Understanding (Discernment)	Conducting workshops that teach the process of spiritual discernment to distinguish God's voice from the many "voices of the world" and to counter the rapidly changing digital tide. This training aims to make faith a moral compass in life decisions, including media consumption.	Overcoming information overload and instant culture.
Faith Literacy on Social Media	Using social media as a means to share the joy of the Gospel in the digital language of young people. This involves creating inspirational content that promotes Gospel values and counters materialistic/individualistic narratives.	Responding to secularization and the use of social media as a barrier to faith.
Supportive Digital Community	Establishing digital Church-Based Communities (KBG) or online catechism groups as safe spaces to share faith struggles aligns with findings that youth participation can occur through digital media. The church plays a role as a community that ignites new hope.	Overcoming individualism and social isolation.

Pastoral Approach

The approach must ensure that the Church becomes a traveling companion for young people, listening to their experiences and helping them discover the meaning of life in a dialogue and with love. Young people should be seen as partners who can enrich the Church with their creativity and service, not simply as pastoral objects.

Measurable Outcome Indicators

These outcome indicators are designed to measure the extent to which the program has successfully addressed specific challenges and encouraged young people to live *Christus Vivit*.

Table 2. Outcome Indicators

Outcome Dimensions	Quantitative Indicators (Measurement Examples)	Qualitative Indicators (Pastoral Objectives)
Church Involvement (Against Individualism)	KBG Participation: Percentage increase in youth participation (both physically and through digital media) in Church and community activities.	Young people realize that they are the Church itself and are actively involved in all Church activities.

Liturgical & Sacramental Involvement	Frequency of active involvement in liturgical services (e.g., being an officiant, organist) or participation in the sacraments of reconciliation/eucharism	Faith is not only inherited, but lived and manifested in every aspect of life.
Spiritual Well-being (Overcoming the Crisis of Meaning/Instant Culture)	The level of spiritual satisfaction and the presence of joy and hope, as measured through surveys or reflection. The presence of joy is a sign of a true faith journey.	Young people find the true meaning of life in the Gospel and show the face of the Church full of joy, solidarity and love.
Call and Mission (Overcoming Secularization)	The number of young people who actively reflect on and answer their vocation through social service or evangelism in their study/work environment.	Faith enables young people to live the Gospel through study, work, and social service, becoming a living witness to the love of Christ.

Examples of Youth Activity Tools

The activity set should support young people to become agents of evangelization and use their creativity.

1. Digital Vocation Quest:
 - Description: A workshop series that encourages quiet reflection to listen to God's voice. This workshop uses digital platforms (e.g., podcasts or live reflective sessions) to discuss how to discover one's calling—which doesn't necessarily mean becoming a monk or nun, but rather a life of service and love wherever one finds oneself.
 - Challenge Focus: Countering social pressures and secular narratives that focus solely on worldly careers, emphasizing that faith is a moral compass for making wise decisions.
2. Youth as the Church:
 - Description: Giving full trust to young people to participate and enrich the Church with their creativity. Example: establishing a youth content team (with pastoral support) that produces short videos, memes, or theological infographics relevant to the digital reality.
 - Challenge Focus: Addressing the view that young people are merely pastoral objects. Instead, they are the Church itself, the living and dynamic body of Christ.
3. Empathy Assistance 292
 - Description: Training for mentors and peers to provide genuine, non-judgmental presence. The goal is to create a safe space for adolescents struggling with doubt, exhaustion, or a spiritual identity crisis caused by

the pressures of the times. Mentoring should be based on love and example.

- Challenge Focus: Addressing the impact of secularization and social pressures that lead to a spiritual identity crisis.

Conclusion

Young people's faith is a dynamic of life that is constantly evolving and changing, as demonstrated by the research findings on Pope Francis' document *Christus Vivit*, Preparatory Document: Young People, the Faith, and Vocational Discernment (2017), and supporting studies from the journal *Fides et Ratio* (2023). The Church must reaffirm its role as a companion on the journey for young people, as requested by Pope Francis through *Christus Vivit*. The Church must listen, accompany, and entrust the mission of Christ's love to them. Young people not only received teachings but also became active members of Church life. They have an extraordinary capacity to portray the optimistic and youthful face of Christ. The faith of young people can be a source of renewal for the Church and society through sincere accompaniment and a deep discernment process. The Church is asked to take an empathetic, relevant, and contextual pastoral approach to the realities of young people's lives in today's modern world, which is full of digital challenges and a crisis of meaning. Thus, the footprints of faith in the life journey of young Christians are not merely a spiritual narrative, but a sign of the living God's presence in the world. Their faith became a spiritual energy that radiated joy, solidarity, and new hope for the Church. Through the active involvement of young people, the Church can continue to live and grow as a dynamic and loving community, in line with the main message of *Christus Vivit* that Christ lives, and He desires that every young person also live in love and hope. The Youth Pastoral Program Design: Traces of Faith in the Digital Space is proposed in this paper with the hope that it can contribute as an implementation guideline.

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STUDENTS' LEARNING OBSTACLES AND DIDACTICAL ANTICIPATION IN LEARNING THE PYTHAGOREAN THEOREM

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Received: 30 September 2025; Accepted: 18 November 2025

Abstract

The Pythagorean Theorem represents a fundamental concept in mathematics education, especially in its application to solving mathematical problems. However, in reality, many students continue to struggle with understanding the concept, resulting in significant learning obstacles. This study aims to investigate the learning obstacles faced by students in learning the Pythagorean Theorem. The study involved 28 eighth-grade students from a junior high school in Riau Province. This study adopts a qualitative design with a case study approach. Data collection was conducted through interviews, written tests, and observations. Data analysis was performed through reduction, presentation, and conclusion. Findings from this study indicate that students faced epistemological obstacles in learning the Pythagorean Theorem, particularly regarding their understanding of key concepts, such as a misunderstanding of the relationship between sides of a right triangle. Ontogenic obstacles were associated with students' lack of learning readiness, particularly their insufficient understanding of triangle-related concepts that serve as foundational knowledge. Didactic obstacles were linked to how the material was presented, such as a lack of visual exploration related to presenting the meaning of the Pythagorean Theorem. The learning obstacles experienced by students help teachers anticipate future learning and outline several didactical anticipations that teachers should consider implementing.

Keywords: didactical anticipation, learning obstacles, Pythagorean theorem

Introduction

Mathematics is a fundamental discipline that plays a significant role in the development of science and technology. The process of learning mathematics is known to require high-level thinking and strategic solutions, which is why mathematics is often considered difficult (Hanan & Sugiman, 2025). One of the main objectives of mathematics learning in schools is to equip students with the ability to understand concepts and apply them to solve real-life problems. However, in practice, many students struggle to comprehend fundamental mathematical concepts. One of these is the Pythagorean Theorem, which serves as an essential foundation for studying geometry, trigonometry, and advanced mathematics.

The Pythagorean Theorem is one of the mathematical concepts taught in 8th-grade junior high school. The Pythagorean Theorem states that in a right triangle, the square of the length of the hypotenuse is equal to the sum of the squares of the lengths of the other two sides (Pangestu & Setyadi, 2020). According to Cholily et



al. (2022), students are required to master basic competencies in the form of conceptual understanding and application of the Pythagorean Theorem in learning. Furthermore, students also need to be able to recognize numbers that satisfy Pythagorean Triples (Ali, 2025).

Although the formula appears simple, students often memorize it without fully understanding its conceptual meaning. As a result, they tend to misunderstand the hypotenuse, misapply the formula, or experience difficulties when working on contextual problems (Pangestu & Setyadi, 2020). In line with the results of research conducted by Maria (2023), it was found that when teachers gave story problems related to real-life material, many students struggled to understand them even though the teacher had explained them several times with detailed and clear solution steps. Furthermore, research conducted by Hikmi (2024), students also had difficulty illustrating problems in the form of triangles that can be calculated using the Pythagorean Theorem. Observations also showed that students had difficulty distinguishing the formulas for determining the length of the hypotenuse from the length of the other sides. Research by Hutapea et al. (2015) confirmed that these difficulties arise because students have not yet understood the concept, resulting in failure to solve problems in different contexts. This kind of help is known as a learning obstacle.

The concept of learning barriers, introduced by Brousseau (2002) and developed within the framework of Didactic Design Research (DDR) by Suryadi (2010), provides a foundation for identifying the causes of student difficulties. Learning obstacles can be divided into three categories: (1) epistemological obstacles, which are difficulties resulting from limited conceptual knowledge; (2) ontogenic obstacles, which are difficulties resulting from student unpreparedness, such as weak mastery of prerequisite material; and (3) didactic obstacles, which are difficulties resulting from inappropriate presentation of material, both in terms of teacher methods and the learning media used.

Learning obstacles can arise from students' low ability to think and reason about the material presented by the teacher, especially if the learning does not align with the students' readiness, resulting in confusion (Maharani & Wahyuni, 2024). Learning obstacles can also be caused by inappropriate acculturation processes in students, resulting in obstacles (Sandra et al., 2025). Learning obstacles result in students not achieving learning objectives, leading to misconceptions or procedural errors. Therefore, teachers require didactic anticipation.

Didactic anticipation plays a crucial role as a teacher strategy to enhance and facilitate student understanding (Buhaerah et al., 2023; Genc & Ergen, 2022; Spreitzer et al., 2023). Didactic anticipation can be achieved through planning learning strategies, selecting appropriate teaching materials, and providing scaffolding to minimize learning obstacles. Therefore, the teacher's role is a key factor in supporting the effectiveness of student learning (Sandra et al., 2025). Teachers need to design effective didactic designs by mastering the material, understanding student characteristics, and creating controlled didactic situations (Brousseau, 2002; Sulistiawati et al., 2015). The use of technology, learning trajectories such as the Hypothetical Learning Trajectory (HLT), and media and AI support can also serve as didactic anticipation that helps reduce learning obstacles (Maharani & Wahyuni, 2024; Panjaitan & Firmansyah, 2019; Raup et al., 2022; Yuliani, 2017).

Based on the background description, this study aims to identify and analyze the learning obstacles faced by students in learning the Pythagorean Theorem. These obstacles are divided into three types: epistemological, ontological, and didactical. To overcome these obstacles in future learning, several didactical strategies are suggested for teachers to consider. It is expected that through these efforts, students will better understand the concept of the Pythagorean Theorem and have fewer difficulties in learning it. Therefore, the results of this study are expected to contribute to improving mathematics teaching, especially in learning the Pythagorean Theorem at the junior high school level.

Method

This research is a qualitative phenomenological study that focuses on observing and understanding phenomena during the learning process. According to Creswell (2015), phenomenological studies aim to discover the essence of the meaning of a phenomenon experienced by several individuals. Recent research also clarifies the framework for applying phenomenological methodology in educational research to understand students' experiences in a deeper learning context (Frontiers, 2022). The purpose of this study was to identify and analyze learning obstacles among junior high school students in Riau Province and to estimate didactic anticipation in teaching the Pythagorean Theorem.

The subjects of this study were 28 eighth-grade students at a junior high school in Riau province. The selected class included students who had already received instruction on the Pythagorean Theorem. Mathematics teachers also served as data sources through interviews. Data collection techniques were conducted through: (1) a five-item essay test to explore students' understanding of the Pythagorean Theorem, including identifying sides, applying formulas, and solving contextual problems; (2) classroom observations to record teacher-student interactions and student responses to the learning process; (3) in-depth interviews with teachers; and (4) documentation.

Data were analyzed using the interactive model of Miles and Huberman (1994), which involves three stages: (1) data reduction, namely selecting and focusing relevant data related to errors, difficulties, and causes of student learning barriers; (2) data presentation, namely organizing data in tables, categories, and descriptive narratives; and (3) concluding, namely identifying patterns of learning barriers and formulating didactic anticipations. To ensure data validity, source triangulation was used (tests, interviews, observations), a strategy considered essential for modern qualitative research because it allows verification and sharpening of interpretations. Triangulation in qualitative research is not only for verification, but also to explore different perspectives and enrich the interpretation of phenomena (Morgan, 2024). The triangulation carried out was in the form of data collection through direct interviews, observations, and surveys.

Findings and Discussion

The results of this study, conducted on eighth-grade junior high school students in Riau Province, showed that students experienced three types of learning obstacles: epistemological, didactic, and ontogenetic. Analysis of the students' work revealed that obstacles arose not only in calculation procedures but also in understanding basic concepts and how teachers presented the material.

Learning Obstacle

Epistemological Obstacle

Epistemological obstacle, namely, difficulties resulting from limited conceptual knowledge. This limitation causes students to become confused when faced with slightly different types of questions, as in Figure 1 below.

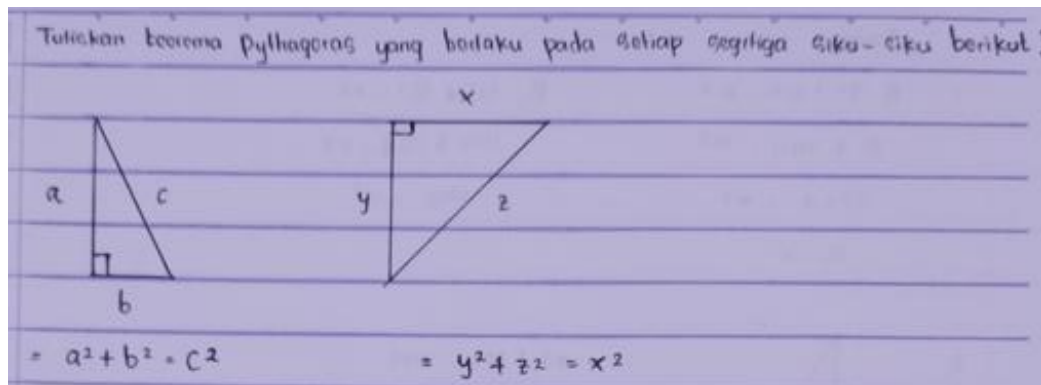


Figure 1. Student Answers Indicating an Epistemological Obstacle

Based on the students' answers in Figure 1, it appears that students were only able to write the Pythagorean theorem in the form $a^2 + b^2 = c^2$, but failed to relate it to the context of the problem. In the example answer, the student only wrote the general form of the theorem without correctly identifying the sides of the triangle. This indicates a misconception in determining the hypotenuse.

Students also frequently made substitution errors, such as swapping the hypotenuse for the perpendicular, resulting in incorrect calculations. These errors indicate students' weak conceptual understanding of the relationship between the sides of a right triangle. This aligns with the findings of Maharani and Wahyuni. (2024), who stated that epistemological learning obstacles often arise because students simply memorize the formula without understanding its conceptual meaning.

Ontogenical Obstacle

Ontogenic obstacles, namely difficulties resulting from student unpreparedness, for example, weak mastery of prerequisite material. This causes students to make quite fatal procedural errors, preventing them from providing correct answers, as shown in Figure 2 below.

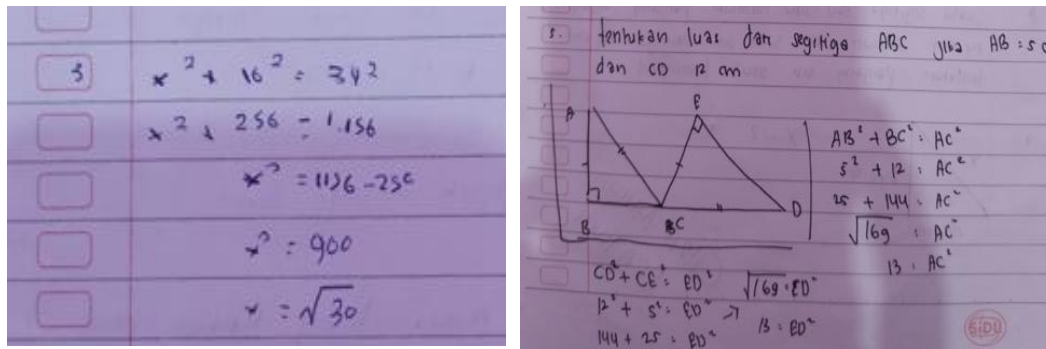


Figure 2. Student Answers Indicating an Ontogenic Obstacle

The student's answers in Figure 2 show errors in operations with square numbers and drawing right-angled triangles. Some students incorrectly calculated square roots, while others were unable to draw right-angled triangles correctly despite explicit instruction.

This indicates that students have not yet mastered prerequisite knowledge, such as the properties of triangles or basic algebraic operations. This obstacle is exacerbated by low learning readiness, as evidenced by students' difficulty solving contextual problems that require more than just number substitution. Rohimah et al. (2024) emphasize that learning content must be structured in alignment with students' learning trajectories to minimize learning obstacles. If prerequisites are not met, students tend to struggle to grasp new concepts.

Didactical Obstacle

Didactic obstacles, namely difficulties resulting from inappropriate presentation of material, both in terms of the teacher's methods and the learning media used. Students are not facilitated to explore their knowledge, thus causing them to be fixated on monotonous problems. This also results in students being less able to explore, such as providing conclusions obtained from working on a problem, as in Figure 3 below.

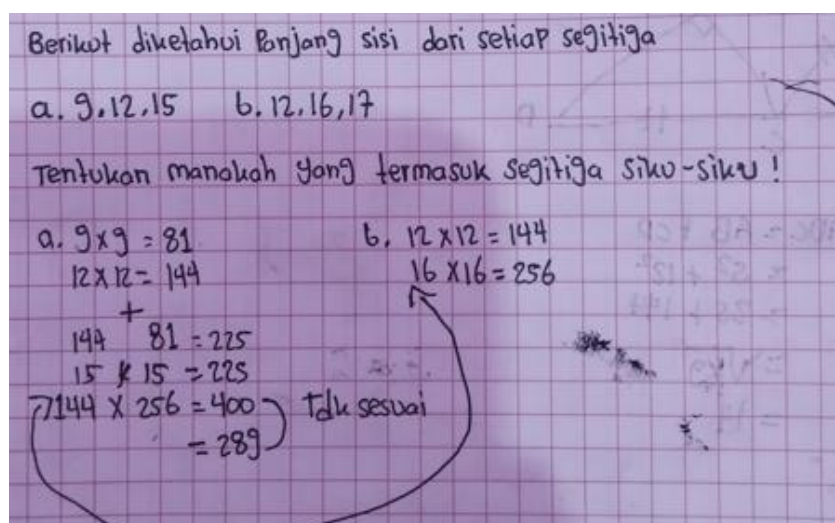


Figure 3. Student Answers Indicating a Didactic Obstacle

The results of student answers in Figure 3 show that the answers tended to be procedural, meaning they simply wrote down the steps for formula substitution without explaining the meaning of the theorem. This aligns with the finding that teachers often emphasize formula memorization over conceptual exploration. As a result, their answers focused solely on algebraic operations, rather than a deep understanding of geometric relationships.

The limited opportunity for conceptual exploration results in students being unable to interpret the meaning of theorems beyond formulas. This finding aligns with Sulistiawati et al. (2015), who emphasized the importance of didactic design in creating optimal learning situations. According to Brousseau (2002), teachers should create didactic situations that allow for active interaction between students, the material, and the teacher, rather than simply delivering procedures.

Didactic Anticipation

Discussions with the teacher also showed that most students still did not understand the concept of the Pythagorean Theorem when given problems that differed from the examples. Students tended to be easily confused, reluctant to explore, and struggled to solve problems related to everyday life. Based on the obstacles identified, several didactic anticipations need to be addressed by teachers to improve the quality of Pythagorean Theorem instruction.

Conceptual Reinforcement through Visual Representations

Teachers need to emphasize conceptual understanding with the aid of visual media, such as the use of real triangles, grid paper, geoboards, or dynamic geometry software (GeoGebra). These visual media can help students see the relationships between the sides of a triangle concretely, so they not only memorize the formula but also understand why it applies. This is consistent with Panjaitan and Firmansyah (2019), who demonstrated that using applications to explore Pythagorean triples can help students better grasp the concept.

Contextual Problem-Based Learning

Teachers can present contextual problems relevant to students' lives, such as measuring the height of a tree, the length of a ladder, or the diagonal distance between a field or simple building designs involving right-angled triangles. Providing contextual problems like this not only makes learning more engaging but also helps students realize that the Pythagorean Theorem has practical uses in everyday life. This way, students understand that the theorem is not just a formula, but also a concrete solution.

Reinforcing Prerequisite Knowledge

Before learning the Pythagorean Theorem, teachers need to ensure that students have mastered the basic concepts of triangles, the properties of sides, and the simple algebraic operations needed to perform quadratic calculations and addition. Mastery of these prerequisites is crucial to avoid confusion when connecting new concepts to existing knowledge. Yuliani (2017) explains that a Hypothetical Learning Trajectory (HLT) is essential for ensuring students' readiness to learn new material.

Collaborative Learning Strategies

Group discussions can be used to allow students to exchange ideas and address misconceptions. The teacher acts as a facilitator, guiding students' thinking toward the correct concept. This aligns with Vygotsky's (1978) learning theory, which states that social interaction is key in knowledge construction; through collaboration, students can help each other within the Zone of Proximal Development (ZPD). The ZPD is the area where students can complete tasks with the support of others before being able to do so independently. Through group discussions, more capable students can provide scaffolding to their peers, while other students have the opportunity to learn from different perspectives. This collaborative approach not only strengthens conceptual understanding but also trains mathematical communication skills, increases self-confidence, and fosters a positive attitude toward mathematics learning.

Balanced Procedural and Conceptual Presentation

Teachers should not only emphasize the formula substitution procedure but also encourage students to explain why the formula applies. For example, through a simple proof activity involving the area of a square plus the side of a triangle. Rittle-Johnson and Schneider (2015) also found that procedural and conceptual understanding develop in a complementary manner; a balanced emphasis helps students not only "know how" but also "know why."

Utilizing Multiple Representations and AI Technology

Teachers can integrate verbal, numerical, graphic, and symbolic representations to accommodate students' learning styles. The presence of artificial intelligence (AI) technology in education, as revealed by Raup et al. (2022), can be utilized to tailor learning paths to students' needs. For example, AI can detect students' weaknesses in understanding the relationship between the squares of triangle sides and then provide additional practice based on dynamic visualizations or simpler contextual problems. Thus, the integration of multiple representations combined with the use of modern technology not only helps students understand the concept of the Pythagorean Theorem more deeply but also enables adaptive, personalized, and inclusive learning.

Conclusion

This study concludes that students face epistemological, didactic, and ontogenetic barriers in learning the Pythagorean Theorem. These barriers have the potential to disrupt competency achievement if not anticipated. Therefore, teachers need to design didactic anticipation through the use of visual media, problem-based learning, scaffolding, and prerequisite assessments. These strategies not only serve to improve students' conceptual understanding of the Pythagorean Theorem but are also expected to make learning more meaningful, interactive, and oriented towards the development of critical thinking and collaborative skills, which are essential in mathematics learning.

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THE IMPLEMENTATION OF PROJECT-BASED LEARNING IN HIGH SCHOOL MATHEMATICS

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Received: 2 November 2025; Accepted: 18 November 2025

Abstract

This study aims to discuss the implementation of mathematics learning at Pangudi Luhur St. Yosef Surakarta High School on the topic of Systems of Linear Equations in Three Variables using the Project-Based Learning (PjBL) model. This study employs a descriptive qualitative approach, using 158 tenth-grade students as subjects. Data were obtained through classroom observation, interviews, and document analysis, including lesson plans, project worksheets, and student work. The results of this study indicate that the mathematics learning process using the Project-Based Learning (PjBL) model is still procedural and lacks connection to real-world contexts. Students tend to imitate the teacher's examples, so the process of exploring ideas, reflecting, and solving problems creatively is not yet optimal. Therefore, students' mathematical creative thinking skills have not developed, and it is necessary to incorporate real-world contexts and reflection at each stage of the project to make mathematics learning more meaningful, mindful, and joyful.

Keywords: contextualization of mathematics learning, creative mathematical thinking, project-based learning

Introduction

The development of critical thinking, creativity, collaboration, and communication skills in learning is one of the criteria for 21st-century education today. Mathematics learning in secondary schools must also keep pace with global needs and Indonesia's Merdeka Curriculum policy (Himmi et al., 2025; Rehman et al., 2024). The Merdeka Curriculum emphasizes the importance of linking tasks to real-world situations that connect academic material to encourage higher-order thinking skills (Himmi et al., 2025). Globally, Project-Based Learning (PjBL) has been recognized as an effective approach to fostering 21st-century skills by increasing motivation, collaboration, and in-depth understanding of mathematical concepts (Rehman et al., 2024). Other studies show that applying the Project-Based Learning (PjBL) model significantly improves students' creative thinking, problem-solving, and collaboration skills compared to conventional learning (Ndiung & Menggo, 2024; Supianti et al., 2025). In addition, the Project-Based Learning (PjBL) model encourages active engagement, learning autonomy, and the relevance of learning to real-world contexts, thereby better preparing students to face the challenges of the times (Rehman et al., 2023, 2024).



The reality on the ground is that the implementation of Project-Based Learning (PjBL) in mathematics classrooms still faces challenges, such as a tendency to carry out projects procedurally, a lack of emphasis on reflection, and limitations in relating projects to the real-life contexts of students (Himmi et al., 2025; Tafara & Masataka, 2023). The success of the Project-Based Learning model is not only measured by the final product, but also by the process of idea exploration, reflection, and knowledge transfer that occurs during learning (Rehman et al., 2024). Strengthening the aspects of meaningful, mindful, and joyful learning in each stage of the project is important with the support of teachers, resources, and adjustments to student characteristics to optimize the development of mathematical creative thinking skills and the contextual relevance of the project (Himmi et al., 2025). Thus, this study discusses in depth the implementation of the Project-Based Learning (PjBL) model on the topic of Systems of Linear Equations in Three Variables at Pangudi Luhur St. Yosef Surakarta High School, identifying factors that support and hinder the development of creative mathematical thinking, as well as the contextual relevance of the project with the principles of deep learning, such as meaningful, mindful, and joyful learning in mathematics learning.

Project-Based Learning in Mathematics

Based on constructivism and experiential learning theories that emphasise active student involvement, the Project-Based Learning (PjBL) model applied in mathematics learning is capable of building knowledge through real experiences, collaboration, and real problem solving (Fisher et al., 2020; Himmi et al., 2025; Zhang et al., 2021). The learning stages in the Project-Based Learning (PjBL) model include identifying contextual problems, designing projects, collecting and analysing data, monitoring, compiling products, and presenting and reflecting. Scientifically, these learning stages foster students' critical thinking, creativity, and collaboration skills (Dan & Xueyan, 2023; Supianti et al., 2025; Zhang et al., 2021). Project-based learning provides students with opportunities to integrate cross-disciplinary knowledge, develop mathematical literacy, and build positive attitudes towards mathematics through meaningful and relevant learning experiences (Hosseini-Mohand et al., 2021; Lazić et al., 2021; Ndiung & Menggo, 2024; Rehman et al., 2024).

The forms of evaluation and assessment in the Project-Based Learning (PjBL) model are not only based on the final product but also involve the process, collaboration, and reflection of students. The instruments used include rubrics, observations, reflection journals, and presentations (Guizado et al., 2024; Guo et al., 2020; Prayekti, 2025). Meta-analysis and experimental research show that the Project-Based Learning (PjBL) model consistently improves learning outcomes, motivation, and 21st-century skills (Jiménez-Gaona & Vivanco-Galván, 2024; Nguyen et al., 2024; Viro et al., 2020). For future research, there is a need to develop learning models that integrate Project-Based Learning (PjBL) with other approaches, as well as to optimise process and product assessment, particularly in the context of technology integration and teacher training (Himmi et al., 2025; Nguyen et al., 2024; Zhang et al., 2021; Zhao, 2024).

Creative Thinking Ability

In 21st-century mathematics education, creative thinking skills are one of the important competencies that enable students to produce new, original, and varied solutions to the problems they face (Munandar, 2009; Siswono, 2009; Wallach & Torrance, 1968). According to Wallach and Torrance (1968), creative thinking has four main aspects, namely fluency, flexibility, originality, and elaboration. In the context of mathematics, this ability can be seen from the diversity of answers, the use of various problem-solving strategies, and the ability to develop and enrich mathematical ideas (Fatmah & Hidayad, 2019; Febrianingsih, 2022; Soeyono, 2014). According to Choridah (2013), Masitoh and Hartono (2017), and Nurhikmayati and Sunendar (2020), creative thinking is not an innate talent but can be developed through appropriate learning, such as open-ended, problem-based learning and project-based learning.

Contextual learning plays a significant role in fostering students' creative thinking skills. By connecting mathematical material to real-life situations or local culture, students are encouraged to relate abstract concepts to their daily experiences, making the thinking process more meaningful and relevant (Anggraini & Zulkardi, 2020; Handayani, 2023; Widodo, 2014). Other studies show that contextual concepts such as ethnomathematics or multiple-solution tasks can improve the fluency, flexibility, and novelty of students' creative thinking (Faiziyah et al., 2022; Yuliastuti et al., 2019). Additionally, problem-based, realistic, and collaborative learning models have been shown to be effective in enhancing creative thinking skills and motivating students to actively explore different alternative solutions (Wardani et al., 2021; Yuliastuti et al., 2019).

Creative and contextual thinking skills not only improve mathematics learning achievement but also equip students with adaptive, innovative life skills and the ability to face global challenges. The relationship between the creative thinking process and creative products, such as the creation of contextual mathematics questions by teachers and students, shows that learning that emphasises exploration, synthesis, and application in real contexts is essential for the development of students' intellectual potential and character (Widodo, 2014). Thus, integrating contextual learning and strengthening creative thinking are key strategies in mathematics education that are relevant to current needs.

Method

This study employed a descriptive qualitative approach to examine the implementation of mathematics instruction on the topic of Systems of Linear Equations in Three Variables using the Project-Based Learning (PjBL) model. The research was conducted at Pangudi Luhur St. Yosef Senior High School in Surakarta and involved 158 tenth-grade students along with mathematics teachers. Data were collected through classroom observations, in-depth interviews, and document analysis of students' project sheets and lesson plans. The instruments used included observation guides, interview protocols, and rubrics for analyzing student work. Data analysis followed the interactive model of Miles et al. (2014), consisting of data reduction, data display, and inductive conclusion drawing. The findings show that while the PjBL model encouraged active student participation, it did not fully cultivate creative mathematical thinking or deepen students' contextual understanding. These results offer insights for developing more

reflective, contextual, and meaningful mathematics learning aligned with the demands of 21st-century education.

Findings and Discussion

Based on the data analysis, two major findings emerged in this study: students' creative mathematical thinking and their contextualization in mathematical project activities.

Students' Creative Mathematical Thinking

The first finding in this study, regarding students' mathematical creative thinking abilities in the project "*Menghitung Biaya dan Keuntungan Produksi Batik Solo*," was that they still tended to be procedural and had not developed optimally in terms of flexibility, originality, and elaboration of ideas. Based on the students' work shown in Figure 1, most groups solved the Systems of Linear Equations in Three Variables using the substitution method, with orderly, systematic calculation steps. Each variable was solved following the teacher's example, with no variation in strategy or in the interpretation of the results. Although the students' work demonstrated mathematical accuracy, it did not exhibit divergent thinking or indications of creativity. This suggests that students were primarily focused on obtaining correct answers rather than on developing broader or more contextual mathematical ideas.

Jenis Batik	Jam	Biaya
Parang	4	180.000
Kawung	5	200.000
Sidomukti	6	230.000

$$\begin{cases} x + y + z = 48 \\ 4x + 5y + 6z = 248 \\ 180.000x + 200.000y + 230.000z = 9.940.000 \end{cases}$$

dibagi 10.000

$$18x + 20y + 23z = 994$$

Model SPLTV

$$\begin{cases} x + y + z = 48 \\ 4x + 5y + 6z = 248 \\ 18x + 20y + 23z = 994 \end{cases}$$

$$\begin{aligned} &\rightarrow x + y + z = 48 \\ &\quad \boxed{x = 48 - y - z} \\ &\rightarrow 4x + 5y + 6z = 248 \\ &\quad 4(48 - y - z) + 5y + 6z = 248 \\ &\quad 192 - 4y - 4z + 5y + 6z = 248 \\ &\quad y + 2z = 56 \\ &\quad \boxed{y = 56 - 2z} \\ &\rightarrow 18(48 - y - z) + 20y + 23z = 994 \\ &\quad 864 - 18y - 18z + 20y + 23z = 994 \\ &\quad 864 + 2y + 5z = 994 \\ &\quad 2y + 5z = 130 \\ &\rightarrow \begin{array}{r} 2y + 5z = 130 \quad \times 1 \\ y + 2z = 56 \quad \times 2 \\ \hline 2y + 5z = 130 \\ 2y + 4z = 112 \\ \hline z = 18 \end{array} \end{aligned}$$

$$\begin{aligned} &\rightarrow x = 48 - (56 - 2z) - z \\ &\quad x = 48 - 56 + 2z - z \\ &\quad \boxed{x = -8 + z} \\ &\rightarrow x = -8 + 18 \\ &\quad \boxed{x = 10} \\ &\rightarrow y = 56 - 2z \\ &\quad y = 56 - 2(18) \\ &\quad y = 56 - 36 \rightarrow \boxed{y = 20} \end{aligned}$$

Figure 1. Students' Answer 1

Figure 1 also shows that the students' thinking process is linear, mechanical, and limited to the formal procedures for solving the Three Variable Linear Equation System concept. The results they obtained were unrelated to contextual factors, such as production time, labour costs, or craftsmen's profits. Meanwhile, Figure 2 shows another group of students who began to show creative thinking. At the bottom of the worksheet, they wrote a simple note that 'the production cost of the *Sidomukti* motif is higher because it takes longer to make.' Although this explanation is not entirely mathematically accurate, it indicates an effort to relate the concept to a real-world concept, which is an early form of flexibility and elaboration of creative thinking. This shows that there are variations in creative thinking abilities among students, as well as opportunities to develop these skills through more intensive reflective guidance.

Jenis Batik	Waktu	Biaya
Batik Parang	4	180.000
Batik Kawung	5	200.000
Batik Sidomukti	6	230.000

Total Produksi = 48
Total Jam Kerja = 248
Total Biaya = Rp9.940.000

Model Matematika

$$\begin{cases} x + y + z = 48 \\ 4x + 5y + 6z = 248 \\ 180.000x + 200.000y + 230.000z = 9.940.000 \end{cases} \rightarrow \begin{cases} x + y + z = 48 & \textcircled{1} \\ 4x + 5y + 6z = 248 & \textcircled{2} \\ 18x + 20y + 23z = 994 & \textcircled{3} \end{cases}$$

Eliminasi $\textcircled{2}$ dan $\textcircled{1}$

$$\begin{array}{r} 4x + 5y + 6z = 248 \quad | \times 1 | \quad 4x + 5y + 6z = 248 \\ x + y + z = 48 \quad | \times 4 | \quad 4x + 4y + 4z = 192 \\ \hline y + 2z = 56 \quad \textcircled{4} \end{array}$$

Eliminasi $\textcircled{3}$ dan $\textcircled{1}$

$$\begin{array}{r} 18x + 20y + 23z = 994 \quad | \times 1 | \quad 18x + 20y + 23z = 994 \\ x + y + z = 48 \quad | \times 18 | \quad 18x + 18y + 18z = 864 \\ \hline 2y + 5z = 130 \quad \textcircled{5} \end{array}$$

Eliminasi $\textcircled{5}$ dan $\textcircled{4}$

$$\begin{array}{r} 2y + 5z = 130 \quad | \times 1 | \quad 2y + 5z = 130 \\ y + 2z = 56 \quad | \times 2 | \quad 2y + 4z = 112 \\ \hline z = 18 \quad \textcircled{6} \end{array}$$

Substitusi $\textcircled{6}$ ke $\textcircled{4}$

$$\begin{array}{l} y + 2z = 56 \\ y + 2(18) = 56 \\ y + 36 = 56 \\ \boxed{y = 20} \end{array}$$

Substitusikan $\textcircled{6}$ dan $\textcircled{4}$ ke $\textcircled{1}$

$$\begin{array}{l} x + y + z = 48 \\ x + 20 + 18 = 48 \\ x + 38 = 48 \\ \boxed{x = 10} \end{array}$$

Kesimpulan = Biaya produksi motif Sidomukti lebih tinggi karena waktu pengerjaan lebih lama.

Figure 2. Students' Answer 2

An interview with one of the students revealed, "We use the substitution method as shown on the blackboard because it is the easiest and most accurate." This statement indicates that learning remains imitative, leaving no room for exploring alternative strategies. Another student said, "We don't know what to write

other than the calculation results, and are afraid of making mistakes if we explain it in words.” This statement illustrates the affective and cognitive barriers that make students hesitate to express their ideas freely. Students do not yet have the confidence to reflect or relate mathematical results to real-world contexts. This condition shows that the principle of mindful learning has not been strongly internalised in the project process.

This study also analysed the Lesson Plans (RPP) used by teachers and found that all stages of Project-Based Learning (PjBL) were included, from problem identification to planning, implementation, and reflection. However, the exploration stage described in the RPP did not provide students with opportunities to discover various solution strategies or develop original ways of thinking. Teachers still focus on uniformity of work steps and accuracy of final results. The results of interviews with teachers reinforce this: ‘Children are often confused when asked to find other ways, so I direct them to use the substitution method so that the results are uniform.’ It is concluded that practicality in learning is prioritised over the development of creativity. This condition makes learning procedural, but lacking in exploration of ideas, so project-based learning loses its essence as a means of fostering creative thinking.

Previous studies, as stated by (Himmi et al., 2025; Rehman et al., 2023), concluded that Project-Based Learning (PjBL) can improve creativity and mathematical problem solving. However, the results of this study show a different reality. When the Project-Based Learning (PjBL) model is implemented without reflective strategies and assessment of the thinking process, students tend to perform tasks mechanically. This gap indicates that the effectiveness of Project-Based Learning (PjBL) is highly dependent on the quality of task design and on teachers’ roles in guiding the exploration of ideas. The urgency of this research lies in the need to strengthen the integration of context, reflection, and creative thinking assessment in every stage of a mathematics project.

This study describes how students at Pangudi Luhur St. Yosef High School in Surakarta demonstrate their mathematical creative thinking skills within a local cultural context, specifically the batik industry in Surakarta. The findings highlight both the challenges and the potential for fostering creative thinking through the implementation of a context-based Project-Based Learning (PjBL) model. Analysis of student worksheets and interviews with teachers and students reveals a clear relationship between project design, teacher strategies, and students’ patterns of thinking that shape the emergence of mathematical creativity.

The findings of this study indicate that teachers remain focused on the accuracy of results and uniformity of procedures, which limits the development of students’ flexible thinking. The role of teachers as facilitators should balance instructional efficiency with opportunities for creative exploration. In the context of 21st-century education, creativity involves not only producing correct answers but also adapting, generating new approaches, and interpreting meaning from real-world contexts. Therefore, it is essential to critically reflect on how teachers facilitate idea exploration and reflective dialogue within each mathematics project.

Students in X Grade at Pangudi Luhur St. Yosef High School are generally unable to apply the concept of Three Variable Linear Equations to real-life contexts in line with the project theme. Students understand mathematics as a set of abstract symbols and formulas, rather than as a tool for explaining life phenomena. In fact,

the ability to apply mathematical knowledge to real-life situations is a key indicator of meaningful learning as expected in the *Merdeka* Curriculum. A guided reflective process will help students realise the relevance of mathematics in their lives and foster an awareness that mathematical thinking does not only occur in the classroom but also in everyday decision-making

Contextualization in Mathematical Project Activities

The second finding of this study indicates that the process of contextualization in mathematics projects has not yet fully established a connection between mathematical concepts and social reality. In the project “*Menghitung Biaya dan Keuntungan Produksi Batik Solo*,” students appeared unable to deeply interpret the relationship between the contextual situation and the mathematical concepts involved. As shown in Figure 3, students listed the variables x , y , and z without explaining their meaning within the context of batik production. Although the students demonstrated accurate mathematical calculations, they did not progress to interpreting the meaning of the results obtained. This suggests that the learning process remains focused on procedural application rather than developing an understanding of the contextual significance of the analysed data.

The image shows a student's handwritten solution to a system of linear equations in three variables (SLK). The equations are:

$$\begin{aligned} 18x + 20y + 23z &= 954 \\ 18x + 18y + 18z &= 864 \end{aligned}$$

The student subtracts the second equation from the first to get:

$$2y + 5z = 130$$

Then, they subtract $2y + 4z = 112$ from $2y + 5z = 130$ to find z :

$$z = 18$$

Next, they substitute $z = 18$ into $2y + 5z = 130$ to find y :

$$y + 2z = 56$$

$$y + 2(18) = 56$$

$$y + 36 = 56$$

$$y = 20$$

Finally, they substitute $y = 20$ and $z = 18$ into the first equation to find x :

$$x + y + z = 48$$

$$x + 20 + 18 = 48$$

$$x + 38 = 48$$

$$x = 10$$

The final solution is boxed on the right:

$$\begin{aligned} x &= 10 \\ y &= 20 \\ z &= 18 \end{aligned}$$

Figure 3. Students' Answer 3

Classroom observations revealed that while most students were actively engaged in group discussions to develop mathematical models, their conversations tended to focus primarily on finding the correct answer. Interviews showed that the batik context had not yet become a meaningful conceptual tool for their thinking.

One student stated, “We know that *Parang* batik is more complicated, but we don’t know how that can be incorporated into the calculations,” while another noted, “When asked to relate the calculations to the craftsmen’s income, we were afraid of getting it wrong because we didn’t know how to explain it.” These responses indicate that students understood the context at a factual level but had not yet connected real-world conditions with the mathematical concepts. They tended to treat the project context as merely a narrative introduction rather than a system that could be represented through mathematical symbols and equations.

	Presentasi dan Refleksi 1. Guru meminta perwakilan kelompok untuk mempresentasikan karyanya 2. Guru meminta semua peserta didik untuk saling melakukan apresiasi terhadap kelompok yang telah mempresentasikan hasil diskusi dan peserta didik yang sudah terlibat aktif dalam pembelajaran.	
Kegiatan Penutup	1. Guru bersama peserta didik melakukan refleksi mengenai pembelajaran yang telah dilakukan, yaitu masalah kontekstual yang melibatkan SPLTV. 2. Guru memberikan tugas sebagai pemantapan pemahaman materi. 3. Guru mengkonfirmasi materi yang akan dibahas pada pertemuan berikutnya yaitu sistem pertidaksamaan linear.	10 menit

Figure 4. Teachers’ Lesson Plan

Analysis of the lesson plan used by the teachers shows that the batik context appears only in the introductory section to attract students’ attention, but is not meaningfully connected to the core learning activities. In the project section, the emphasis remains on solving Systems of Linear Equations in Three Variables through procedural steps. No activities were included that explicitly encouraged students to interpret their calculation results or reflect on their economic meaning. Figure 4 shows that the Lesson Plan used only included a presentation of results in the closing section, without any reflective instructions to relate mathematics to real life. This condition indicates that contextualization within the project activities remains superficial and has not yet become an integral part of students’ mathematical thinking processes.

During the interview, the teacher explained, ‘I use batik as an example to make students more interested in learning, but they still focus only on the calculations.’ This indicates that although the teacher has attempted to incorporate local cultural context into the learning process, the strategies employed have not fully supported the development of deep contextual understanding. Teachers do not play a strong enough role as facilitators who encourage reflection, so students are not yet accustomed to interpreting the meaning of real situations through mathematical language.

The use of the Project-Based Learning model in mathematics learning at Pangudi Luhur High School, on the topic of Systems of Linear Equations in Three Variables, has revealed a discrepancy between the principles of contextual learning in theory and their implementation in practice. Conceptually, this mathematics learning uses a project-based model that links mathematics to real-life contexts, which is expected to improve students' meaningful understanding and engagement. However, in reality, real-world contexts are often used only as a perspective, not as a source of knowledge that encourages analytical and reflective thinking. This shows the importance of teacher support in facilitating the process of connecting mathematical models to the real-world situations students face.

Conclusion

This study shows that the implementation of project-based mathematics learning on the topic of Systems of Linear Equations in Three Variables has been carried out in stages, but has not fully fostered mathematical creative thinking skills or a deep contextual understanding. Students tend to focus on procedural accuracy without exploring the real context of the local batik industry culture in Surakarta. Students only interpreted the context as a story background, not as a conceptual thinking tool. The results of the analysis of student projects, interviews, and lesson plans showed that the process of reflection and communication of understanding had not been facilitated ideally. This indicates a difference between the principles of contextual learning in theory and their implementation in practice, which remains oriented towards the final result. This study highlights the need for a more reflective, context-based project design, as well as for optimizing teachers' roles as facilitators by helping students relate mathematical concepts to real-life situations, so that mathematics learning can become a means of developing creativity, reflection, and meaningful understanding.

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DEVELOPING AN ELECTRONIC STUDENT WORKSHEET WITH PROCESS DIFFERENTIATION FOR THE CHEMICAL KINETICS TOPIC

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Received: 2 November 2025; Accepted: 12 November 2025

Abstract

This study develops and evaluates an electronic student worksheet with process differentiation for the topic of chemical kinetics. It is motivated by students' difficulties in understanding the complex concepts of chemical kinetics and the persistence of conventional teaching methods. The worksheet was developed using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) and tested on 21 eleventh-grade high school students. Data were analyzed through N-Gain calculations and response percentages. The results indicate that the worksheet meets the feasibility criteria. Expert validation showed that the worksheet is highly feasible, with average scores of 92% for content, 88.8% for activities, 95% for appearance and visuals, and 93.3% for language, resulting in an overall average of 92.4%. Practicality was confirmed by students' high positive responses, who strongly agreed that the worksheet was engaging and easy to use. Effectiveness was demonstrated through N-Gain analysis, with improvements in learning outcomes for auditory (0.64), visual (0.69), and kinesthetic (0.68) learners, all categorized as "Medium." Thus, the student worksheet is proven effective, practical, and feasible for improving learning outcomes in chemical kinetics, offering an innovative alternative learning resource that accommodates diverse student characteristics.

Keywords: chemical kinetics, electronic student worksheets, process differentiation

Introduction

Chemistry is often perceived as a difficult subject for students (Priliyanti et al., 2021). Many chemistry concepts, including chemical kinetics, involve phenomena that cannot be directly observed, which leads to low student interest in learning the topic (Siregar et al., 2024). The topic of chemical kinetics requires reasoning skills and often causes difficulties in understanding. Chemistry learning in schools tends to be dominated by lecture-based teaching and assignments, which do not sufficiently encourage students to actively construct their own understanding (Sariati et al., 2020). Monotonous activities and conventional learning strategies that focus too much on classroom instruction without considering students' needs or interests may lead to low learning outcomes (Laia et al., 2022).

Each student differs in understanding, prior knowledge, and learning pace; some require more support, while others are ready for greater challenges. Additionally, students' learning interests vary: those interested in a topic are more



motivated to study deeply, while those less interested need different approaches to spark engagement (Diastono et al., 2018). Learning style refers to how students receive and process new information. There are three types of learning styles: visual (learning through observation, such as diagrams and videos), auditory (learning through listening, such as discussions and lectures), and kinesthetic (learning through physical and hands-on activities, such as experiments) (Sudiana et al., 2019). Referring to the three elements: content, process, and product, differentiation is expected to optimize each student's learning potential, increase engagement and motivation, and create an inclusive learning environment (Herwina, 2021).

Learning style refers to the approach chosen by students in receiving and processing new information. It is categorized into visual learning style (facilitating learning through observation, such as diagrams and videos), auditory learning style (enabling learning through listening, such as discussions or lectures), and kinesthetic learning style (facilitating learning through physical or hands-on activities, such as experiments) (Sudiana et al., 2019). Understanding these learning styles is crucial in process differentiation, a teaching strategy in which teachers adapt instructional methods, tools, and learning activities to match each student's learning needs and preferences, enabling them to learn in the most effective way (Aprima & Sari, 2022).

The rapid development of technology has the potential to transform students' learning methods. One innovative teaching material that can be utilized is the Electronic Student Worksheet (ESW). ESW enables more interactive learning as it is equipped with images, videos, and simulations, helping students visualize complex chemical concepts more easily. Furthermore, ESW is easily accessible, allowing students to learn independently, review difficult materials, and explore topics at their own pace (Sari & Purwaningsih, 2019).

ESW is designed systematically and interactively, often equipped with various multimedia features such as animations, images, videos, and navigation tools that enable direct user interaction with the program. As a digital learning material, ESW not only provides textual content but also includes visual and audio elements that enrich the learning experience (Budiasih et al., 2022). The use of ESW encourages students to be more actively involved in the learning process, such as by watching educational videos, reading materials, conducting simulated experiments, engaging in discussions, and answering embedded questions. Thus, ESW serves as an engaging, active, and adaptable learning resource that supports effective learning (Sariani & Suarjana, 2022).

In implementing the ESW with process differentiation, this can be done by providing various learning activities or using media tailored to the needs of each individual. By accommodating the diversity of learning needs, process differentiation can optimize each student's potential, enhance understanding, and create more effective learning (Azura et al., 2019). Process differentiation allows educators to vary how students learn and demonstrate understanding. In the implementation of ESW and Discovery Learning, this can be achieved by offering a range of activities or media adapted to individual needs. Thus, process differentiation can optimize potential, enhance comprehension, and create effective learning experiences for all students. These issues and phenomena underpin this research, which aims to develop an ESW using the Discovery Learning Model based on Process Differentiation in the topic of Chemical Kinetics. This study is

expected to produce an ESW that is valid, practical, and effective in improving students' understanding of chemical kinetics.

Method

This study employed a Research and Development (R&D) approach using the ADDIE model, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation (Yahya et al., 2024). In the analysis stage, researchers identified students' needs, characteristics, and learning difficulties related to chemical kinetics through interviews with chemistry teachers and students from grades XI–XII. The design stage involved creating instructional materials based on the analysis results. During the development stage, the product was constructed, validated by experts, and revised according to feedback. The implementation stage consisted of a limited trial with 21 grade XI students at Pangudi Luhur St. Louis IX High School implementing the Merdeka Curriculum. The evaluation phase assessed the product's validity, effectiveness, and practicality (Hasniyah & Muchtar, 2021).

Findings and Discussion

The ADDIE development model involves several stages: analysis, design, development, implementation, and evaluation. The first stage consists of analyzing student and teacher needs, analyzing materials, and learning media. This analysis aims to determine the needs and circumstances of students in schools implementing the Merdeka Curriculum.

Based on the results of the observation analysis, difficulties arose for the teachers when **preparing learning materials and media**, which could lead to **misconceptions**. In addition to causing misconceptions, teachers also need time to prepare materials and learning media integrated with a learning model. For students, **chemical kinetics material can be difficult and requires engaging learning methods**. Based on the interview results with the chemistry teacher at Pangudi Luhur St. Louis IX Senior High School, students felt that the learning provided tended to be **overly reliant on the textbook, making them bored and not meeting their learning needs in line with their interests**. Thus, based on the analysis with the chemistry teacher at Pangudi Luhur St. Louis IX Senior High School, it is known that the use of **ESW is highly necessary** for assigning tasks to students, as well as a means of student assessment.

After completing the analysis phase, the next step is the design phase. The design phase is the stage of product development, which begins with the creation of a storyboard, the design of the media, and assessment. The creation of the storyboard and the chemistry content is designed using Microsoft Word. The chemistry content, which consists of the learning stages or learning scheme, begins with the creation of learning activities adapted to the stages of discovery learning and descriptions of each learning activity. The media design involves the use of audio, video, images, and interactive simulations included in the ESW, with the design being created by Canva. The product design is presented in Figure 1. The assessment design is carried out by creating a blueprint for the test items, followed by writing the questions on Quizizz so that they can be accessed by students via a link included in the ESW. Thus, the final media product is an ESW provided to

students in the form of a Google Sites link that was developed to cover chemical kinetics material with process differentiation for Phase F (Grade XI).



Figure 1. The Product Design for Auditory, Visual, and Kinesthetic Learning Style

The next step, which is the development stage, includes the development of the ESW content, the development of competency test questions, and a feasibility test by validators, as well as the results of the feasibility test. The ESW content development is adapted to the auditory, visual, and kinesthetic learning styles of the students. The development of competency test questions is carried out according to the blueprint of the item set, created in the form of multiple-choice questions, and used for the pretest and posttest. The product feasibility test is conducted by 3 validators, while the feasibility test of the competency questions and the product use questionnaire is conducted by 2 validators. Comments and suggestions are provided to serve as a guide for product refinement so that the product can be declared suitable for trial. According to Akker et al. (2006), a development product must meet the criteria of being valid, practical, and effective. Akker et al. (2006) further explain that the product must meet the validity criteria to obtain a quality product. Furthermore, the development product must satisfy the practicality criterion because a development product is considered good quality if the product users assess the product as easy to use and applicable. If these are met, the development product must also fulfill the effectiveness criterion, which indicates that the developed product has successfully achieved the expected goals.

Table 1. Score of Product Quality Assessment

Assessment of product quality	Validity (%)	Category
Content	92.5	Very Valid
Learning Activity	88.8	Very Valid
Illustration and Design	95	Very Valid
Language feasibility	93.3	Very Valid
Average	92.4	Very Valid

Based on Table 1, four aspects of validation were conducted on the ESW. Based on the product validation results by three validators, four validation aspects of the ESW product have a validity level of "Very Valid". Thus, the product is declared worthy of being tested; however, with suggestions provided by the three validators. After the product is validated, it is then implemented or tested on students. The practicality of the developed product is identified by the results of the student response questionnaire, and the effectiveness of the developed product is identified by the results of the comparison of pre-test and post-test scores by calculating N-Gain.

Table 2. Results of the Analysis of the Practicality Level of the ESW Product

Assessment aspects	Total score	Maximum score	Level of agreement
Learning media	695	840	Strongly Agree
Material	275	315	Strongly Agree
Benefits	241	315	Agree
Total	1211	1470	Strongly Agree

Based on Table 2, the respondents' responses to the statement items showed that the majority of respondents chose the assessments "Agree" and "Strongly Agree". In the learning media aspect, the average response assessment was "Agree". In the material aspect, the response assessment was "Strongly Agree". In the benefit aspect, the average response assessment was "Agree". The analysis results with the level of respondent agreement "Agree" and "Strongly Agree" strengthen that the objectives to be achieved by the product, with process differentiation in the chemical kinetics material used by students, are easy to use and practical. According to Riyadi et al. (2014), a learning tool is said to be practical if it meets the practicality aspect, namely that the tool developed can be applied. The practicality test stage, carried out by giving a response questionnaire to students, was carried out to determine the ease of use of the product (Andriana & Kartolo, 2022). Thus, the ESW with process differentiation learning in the chemical kinetics material is practical because it meets the learning media aspects, material aspects, and benefit aspects that have been designed by the researcher.

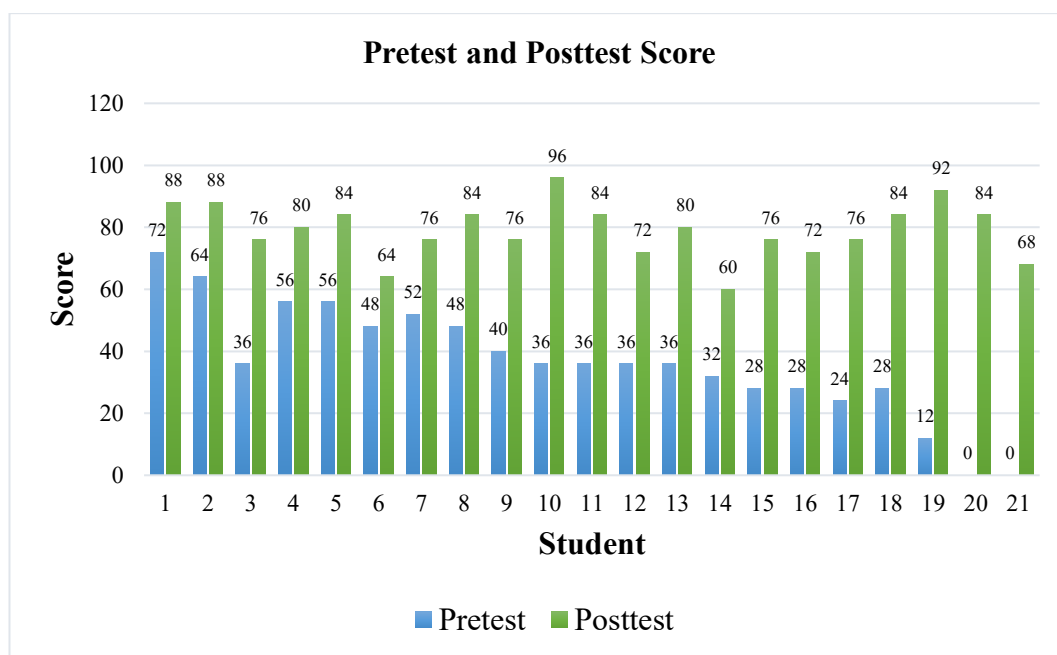


Figure 2. Value Comparison of Pretest and Posttest Scores

Based on Figure 2, the competency test results obtained from the pretest and posttest scores generally showed an increase from PD1 to PD21. Therefore, the increase in scores indicates positive progress or the desired outcome. The next analysis to prove the effectiveness of the competency test was an N-Gain test.

Table 3. Results of the N-Gain Score for Auditory Learning Style

No	Student	Score	
		Pretest	Posttest
1.	APD ₁	72	88
2.	APD ₂	64	88
3.	APD ₅	56	84
4.	APD ₉	40	76
5.	APD ₁₃	36	80
6.	APD ₁₆	28	72
7.	APD ₁₇	24	76
Average		45.71	80.57
N-Gain Score		0.64	Moderate

Based on Table 3, the results of the N-Gain score pretest-posttest on students with auditory learning styles obtained an average N-Gain score of 0.64. According to Majdi, Subali, & Sugianto (2018), the average N-Gain value is included in the “moderate” category if $0.3 < g \leq 0.7$.

Table 4. Results of the N-Gain Score for visual learning style

No	Student	Score	
		<i>Pretest</i>	<i>Posttest</i>
1.	VPD ₃	36	76
2.	VPD ₁₁	36	84
3.	VPD ₁₂	36	72
4.	VPD ₁₄	32	60
5.	VPD ₁₈	28	84
6.	VPD ₁₉	12	92
Average		30	78
<i>N-Gain Score</i>		0.69	Moderate

Based on Table 4, the results of the pretest-posttest N-Gain Score test on students with a visual learning style obtained an average N-Gain score of 0.68. According to Majdi, Subali, & Sugianto (2018), the average N-Gain value is included in the “moderate” category if $0.3 < g \leq 0.7$.

Table 5. Results of N-Gain Score Calculation for Pretest and Posttest of Kinesthetic Learning Style

No	Student	Score	
		<i>Pretest</i>	<i>Posttest</i>
1.	KPD ₄	56	80
2.	KPD ₆	48	64
3.	KPD ₇	52	76
4.	KPD ₈	48	84
5.	KPD ₁₀	36	96
6.	KPD ₁₅	28	76
7.	KPD ₂₀	0	84
8.	KPD ₂₁	0	68
Average		33.5	78.5
<i>N-Gain Score</i>		0.68	Moderate

Based on Table 5, the results of the pretest-posttest N-Gain test on students with a kinesthetic learning style obtained an average N-Gain score of 0.67. According to Majdi, Subali, & Sugianto (2018), the average N-Gain value is included in the “moderate” category if $0.3 < g \leq 0.7$.

Table 6. Results of the overall N-Gain Score

No	Student	Score	
		<i>Pretest</i>	<i>Posttest</i>
1.	APD ₁	72	88
2.	APD ₂	64	88
3.	VPD ₃	36	76
4.	KPD ₄	56	80
5.	APD ₅	56	84
6.	KPD ₆	48	64
7.	KPD ₇	52	76

No	Student	Score	
		<i>Pretest</i>	<i>Posttest</i>
8.	KPD ₈	48	84
9.	APD ₉	40	76
10.	KPD ₁₀	36	96
11.	VPD ₁₁	36	84
12.	VPD ₁₂	36	72
13.	APD ₁₃	36	80
14.	VPD ₁₄	32	60
15.	KPD ₁₅	28	76
16.	APD ₁₆	28	72
17.	APD ₁₇	24	76
18.	VPD ₁₈	28	84
19.	VPD ₁₉	12	92
20.	KPD ₂₀	0	84
21.	KPD ₂₁	0	68
Average		36.57	79.04
<i>N-Gain Score</i>		0.67	Moderate

Based on Table 6, the calculation of the N-Gain test for each learning style yielded an average score for students with an auditory learning style of 0.64, which falls into the medium category. The average score for students with a visual learning style was 0.69, and also belonged to the medium category. The average score for students with a kinesthetic learning style was 0.68, also in the medium category. Based on each average score obtained, it can be identified that the highest N-Gain score was for the visual learning style, followed by the kinesthetic learning style, and the lowest was the auditory learning style. However, the obtained data show that the three average scores are not significantly different and all fall into the medium category (Majdi et al., 2018). This indicates that the ESW with process differentiation learning on chemical kinetics material is quite effective in improving student learning outcomes or abilities according to their respective learning styles. Therefore, the implemented ESW with process differentiation on chemical kinetics material is statistically proven effective in increasing student learning outcomes. The level of this increase's effectiveness, when measured using N-Gain, is in the "Medium" category (average N-Gain 0.67), meaning it successfully achieved the potential increase expected by the authors (Septiyani, 2015). Learning outcomes or abilities according to their respective learning styles. Therefore, the implemented ESW with process differentiation on chemical kinetics material is statistically proven effective in increasing student learning outcomes. The level of this increase's effectiveness, when measured using N-Gain, is in the "Medium" category (average N-Gain 0.67), meaning it successfully achieved the potential increase expected by the authors (Septiyani, 2015).

The next stage is the evaluation stage, where the student responses are gathered to assess the product. This is done by having students fill out a response questionnaire containing comments and suggestions regarding the use of the ESW with process-differentiated instruction on the topic of chemical kinetics. The evaluation is carried out based on the comments and suggestions provided for the product developed by the researcher to ensure the product is suitable for the learning

process. The students' assessment indicates that the developed ESW with process differentiation on the topic of chemical kinetics is highly suitable for the learning process, engaging, easy to use, and provides an appealing learning experience that aligns with the students' learning styles.

Conclusion

Based on the results of research and development of ESW with Process Differentiation Learning on Chemical Kinetics Material, it can be concluded that the product incorporating process differentiation learning on the topic of chemical kinetics was successfully developed using the ADDIE development model. The product has met the criteria of valid, effective, and practical. The product has a "Very Valid" level of validity with a validity score of 90.2%. The product's level of effectiveness, measured using N-Gain, is in the "Moderate" category, with N-Gain scores for the auditory learning style is 0.64, the visual learning style is 0.69, and the kinesthetic learning style is 0.68. This indicates that the ESW with process differentiation learning on chemical kinetics material is quite effective in improving students' learning outcomes or abilities in accordance with their learning styles. From the practicality aspect, the ESW obtained a score of 1211, with the respondents' level of agreement in the "Strongly Agree" category regarding the statements in the response questionnaire. This shows that the developed product is considered practical, easy to use, and can be implemented in learning.

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HEARTS IN THE LAB, HANDS FOR THE EARTH: AI BIOINFORMATICS IN RURAL EDUCATION (A PHENOMENOLOGY STUDY)

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Received: 5 November 2025; Accepted: 24 November 2025

Abstract

This study explored the integration of technology (AI and bioinformatics) in socio-ecological projects as a means of strengthening character values among high school students who enrolled in biotechnology for young learners. These students came from three different schools in Northern Luzon, Philippines. Conducted within a biotechnology enrichment class for young learners, the project encouraged students to address real-world environmental challenges in the rural communities of Tuguegarao, Gataran, and Antipolog in the Northern Philippines. The learning cycle comprised three phases: students were first introduced to innovative technologies and applications; they then investigated issues affecting local rivers and soils; and finally, leveraging AI and related applications, they designed enzymes with potential use in bioremediation.

Guided by a qualitative phenomenological approach, this research focused on the lived experience of students for their experienced character development, scientific engagement, and rich personal reflections from students. The observation class, students' reflection, and the deep interview were compiled and clustered into a coding system with pointers: basic skills on AI and biotech before joining the program, empathy, critical thinking, collaboration, and a sense of social responsibility.

Beyond technical skills in AI and bioinformatics, the project fostered empathy, critical thinking, collaboration, and a sense of social responsibility. The findings highlight the potential of technology-based socio-ecological projects not only to enhance scientific literacy but also to cultivate character values essential for human dignity and ecological sustainability. This approach demonstrated how integrating AI-driven biotechnology education with local environmental contexts can empower youth to become ethically grounded innovators in addressing global challenges.

Keywords: AI, biotechnology for young learners, future global education, phenomenology research, socio-ecological project

Introduction

The rapid advancement of artificial intelligence (AI) and bioinformatics has opened new opportunities for transforming science education, particularly in the context of secondary-level biotechnology programs. Biotechnology education for young learners has traditionally emphasized laboratory skills, fundamental



biological concepts, and the ethical implications of genetic and environmental interventions. However, the integration of computational technologies, such as AI-driven modelling and bioinformatics tools, provides unique avenues for enhancing not only technical literacy but also the character development of students who are increasingly positioned as future innovators and problem-solvers (Timmis et al., 2017).

In the Philippine context, biotechnology education remains in its formative stage, especially at the high school level, where enrichment classes and specialized programs are limited to select schools. However, local environmental issues such as river pollution, soil degradation, and improper waste management demand innovative and socially responsible solutions. Embedding AI and bioinformatics into socio-ecological projects gives students the opportunity to directly connect scientific inquiry with their lived realities, thereby cultivating empathy, collaboration, and social responsibility alongside critical thinking skills (Prensky, 2010).

Previous studies have highlighted the role of technology-driven learning in shaping student engagement and value. For example, Kim and Reeves (2007) found that project-based learning involving real-world challenges improved collaboration and reflective thinking among school students. Similarly, Timmis et al. (2017) argued that digital tools can support identity formation in learners as they position themselves within scientific communities. These findings suggest that embedding AI and bioinformatics in community-based projects has the potential to strengthen students' scientific identity and moral awareness.

This study is situated within biotechnology enrichment classes for high school students in Northern Luzon, Philippines. It focuses on learners from three schools who engaged in a three-phase project cycle: (1) introduction to AI and bioinformatics tools, (2) investigation of environmental issues in local rivers and soils, and (3) the design of enzymes for potential bioremediation applications. Through a qualitative phenomenological approach, the study aims to explore students' lived experiences in these activities, particularly how their engagement fostered character development, empathy, collaboration, and critical thinking.

The specific objectives of this study are to:

1. Examine how the integration of AI and bioinformatics influenced students' understanding of biotechnology concepts and applications.
2. Explore students' reflections on their personal values and social responsibilities as they worked on socio-ecological projects.
3. Identify the ways in which collaborative learning in biotechnology projects shaped their interpersonal and scientific engagement.

This paper begins with a review of related literature on technology integration, project-based learning, and character education in science. It then presents the methodological framework of the phenomenological study, followed by findings from student reflections and project outputs. The discussion highlights how AI-driven biotechnology education can simultaneously promote scientific literacy and character development, and the conclusion emphasizes its implications for future science pedagogy in the Philippine context and beyond.

Method

Research Context and Participants

The study was conducted within the Biotechnology for Young Learners program facilitated by Kryacademia, an enrichment academy providing specialized science education to high school students in Northern Luzon, Philippines. The Participants included students from three partner schools who voluntarily enrolled in the biotechnology enrichment classes. The class emphasized AI applications, bioinformatics, and their integration in socio-ecological projects addressing real-world challenges in local communities.

Data Sources

The primary sources of data were threefold: (1) classroom observations conducted by the researcher, (2) in-depth discussions with students to align with the phenomenological approach, and (3) students' outputs, including assignment completions and reflective journals. The journals, completed at the conclusion of each project phase—(a) introduction to AI and bioinformatics, (b) community investigation of river and soil issues, and (c) enzyme design for bioremediation—documented the students' personal reflections, experiences, and perceptions of their learning and character development. These were further supported by project artifacts (such as enzyme design proposals), which provided additional evidence of student engagement and understanding.

Research Design

This study employed a qualitative phenomenological approach, which seeks to describe and interpret the lived experiences of participants in order to uncover the essence of the phenomenon under study (Moustakas, 1994). The Interpretative Phenomenological Analysis (IPA) was applied to this study, aimed to explore in detail how participants made sense of their personal and social world. In this case, the phenomenon of interest was the experience of integrating AI and bioinformatics into socio-ecological projects and its perceived influence on student character and scientific engagement. Kahija (2017) mentioned this approach involved a detailed examination of the participants' experiences, attempts to explore personal experience, and was concerned with an individual's personal perception or account of an object or event, as opposed to an attempt to produce an objective statement of the object or event itself.

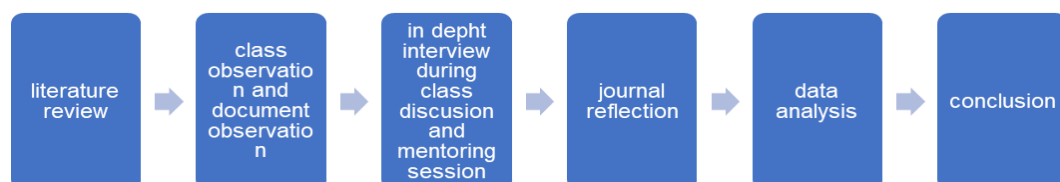


Figure 1. Research Design

Data Collection Procedure

Students were asked to write reflective journals guided by prompts that encouraged them to express their thoughts on scientific engagement, personal growth, collaboration, and social responsibility. These reflections were submitted electronically through a secure platform provided by Kryacademia. Project artifacts were also collected and reviewed to triangulate student perspectives with their tangible outputs.

Data Analysis

Data analysis followed a thematic coding process. First, all reflective journals were transcribed into text files and organized by participant codes (e.g., Student 01, Student 02). The researcher engaged in open coding to identify recurring ideas and experiences, followed by axial coding to cluster these into themes related to character development, empathy, collaboration, and critical thinking (Strauss & Corbin, 1998). Thematic patterns were then validated by cross-referencing with project artifacts and observation notes to ensure credibility and trustworthiness.

Ethical Considerations

All participants were informed of the purpose of the study and provided consent prior to participation. Anonymity was ensured by assigning codes to participants instead of names. Participation was voluntary, and students were informed that their decision whether or not to participate would not affect their academic standing in any way.

Findings

and

Discussion

Findings on Students' Background in Biotechnology and Bioinformatics

The participants in this study came from three secondary schools located in the province, where access to advanced technology and digital resources is limited. This context is significant, as it shaped both their prior knowledge and their initial engagement with biotechnology and bioinformatics.

Table 1. Students background

Name of School	Province	Number of students	Background
SPUP	Cagayan	8	Tuguegarao City is a rapidly developing provincial capital in Cagayan Valley that serves as a major educational centre
PPIS	Rizal	1	scenic city on the slopes of the Sierra Madre east of Metro Manila — known as a pilgrimage/tourist destination with viewpoints, local handicrafts and a cooler, greener environment compared to Metro Manila

CDNHS	Cagayan	3	Gattaran is largely rural/coastal with notable natural sites (shell middens, caves, springs, falls) and a tropical monsoon climate; schools here are typically in a more rural, community-centered environment
Total		12	

Students' responses revealed that they had minimal background in biotechnology and no practical exposure to bioinformatics before the project. Their understanding of biotechnology was mostly drawn from classroom discussions, often limited to theoretical concepts. For example, while they were familiar with the idea of biotechnology in agriculture or health, they had not encountered its application through computational tools or problem-based projects.

When introduced to bioinformatics and artificial intelligence, many students described the experience as entirely new and technically overwhelming. One participant shared that "observing the proteins was the most challenging part," while another admitted that "everything looked complicated—especially with coding." Such reflections highlight how their rural school settings, with limited access to technology, contributed to their lack of prior experience in computational biology.

Despite these constraints, the provincial students demonstrated adaptability by engaging with tasks that were far beyond their usual academic exposure. The data show that they entered the project from a position of limited access and limited background knowledge, yet were able to build an initial foundation for understanding how biotechnology and bioinformatics intersect.

In summary, the findings confirm that the students' backgrounds were shaped by their context: three provincial schools with restricted access to technology, resulting in minimal prior exposure to bioinformatics. This context makes their subsequent learning experiences and reflections particularly meaningful, as it underscores the transformative role of introducing advanced scientific concepts to learners in resource-limited educational environments.

Findings on Students' Perception of Including AI and Bioinformatics in Biotechnology

The students' reflections revealed varied but generally positive perceptions of the integration of artificial intelligence (AI) and bioinformatics in biotechnology. Three themes emerged: **recognition of complexity, appreciation of innovation, and relevance to science learning.**

Recognition of complexity and difficulty.

Students acknowledged that integrating AI into biotechnology was not an easy process. They described tasks such as protein modelling, coding, and problem identification as overwhelming at first. One participant reflected that "the most challenging part was observing the proteins. It was hard to understand how they were modelled and how AI could predict their structures." Another noted that

“everything looked complicated—especially with coding,” underscoring the steep learning curve they experienced when encountering AI and bioinformatics tools.

Appreciation of innovation and potential.

Despite the challenges, students recognized the significance of integrating AI and bioinformatics into biotechnology. They expressed appreciation for how technology could deepen understanding of biological systems and open possibilities for problem-solving. As one participant described, “it was exciting to see how technology and biology can work together,” while another reflected that it was “amusing...everything that was displayed as a 3D structure is a part of us humans.” Such statements highlight students’ perception that AI does not replace biology but enriches its application.

Relevance to their identity as science learners.

Students also perceived the integration of AI and bioinformatics as transformative for their growth as learners. They emphasized how the experience expanded their understanding of what science could encompass, moving beyond textbooks to computational tools and applied problem-solving. One participant explained that the program “expanded my learning area as a science learner—that there was more to study and explore,” suggesting that students valued the inclusion of AI and bioinformatics as a way to broaden their scientific identity.

In summary, students perceived the inclusion of AI and bioinformatics in biotechnology as both challenging and meaningful. While they struggled with the technical complexity, they also recognized its innovative role in advancing biotechnology and acknowledged its importance in shaping them as science learners.

Findings on Students’ Personal Values and Social Responsibilities

The students’ reflective journals revealed that engaging in biotechnology and bioinformatics projects extended beyond technical learning; it also fostered growth in personal values and strengthened their sense of self. Three main themes emerged: environmental concern, empathy and responsibility, and the value of collaboration.

Heightened environmental concern

Students consistently connected their scientific activities with the environmental issues they observed in their communities. One participant noted that “*many rivers are either dried up or so polluted that they have a strong smell,*” which led them to recognize that science should address urgent ecological problems. Another emphasized that “*the whole part of actually dedicating a project against plastic and water pollution is already a proof about the responsibility we have as part of the society.*” These reflections show that students internalized environmental responsibility as a core value linked to their scientific work.

Empathy and responsibility toward the community

The reflections also highlighted how students began to see science as a tool to serve people. Observing the state of rivers and soils evoked empathy, with one student expressing, “I felt empathy when I saw how damaged the rivers were, since the community relies on them for water and livelihood.” This sense of empathy translated into responsibility, as another student described joining clean-up drives

after conducting their study. Such accounts suggest that students recognized the interconnection between environmental care and community well-being.

The value of collaboration and collective responsibility

Through their group projects, students reflected on the importance of collaboration, not just for completing tasks, but also for cultivating responsibility toward one another and society. One participant emphasized that “collaborating with my teammates was the most meaningful part,” explaining how shared ideas created both memorable experiences and purposeful innovation. Even students who worked independently expressed that balancing different roles in their project pushed them to think critically about responsibility and sustainability.

In summary, students’ engagement in biotechnology and bioinformatics fostered personal values of empathy, environmental concern, and collaboration, while also strengthening their sense of social responsibility. Their reflections show that the project went beyond technical learning, encouraging them to see themselves not only as students of science but as active contributors to society and the environment.

The data in Table 1 summarizes the students’ learning progress throughout the biotechnology and bioinformatics enrichment class. Overall, students demonstrated high levels of understanding across cognitive, affective, and social dimensions of learning. While 85% of students showed an adequate grasp of basic biotechnology concepts, slightly fewer (72%) were able to confidently use bioinformatics tools such as protein modeling and coding applications. Nevertheless, this still reflects a promising outcome given that many students had no prior experience with computational biology.

Students’ reflections revealed a meaningful cognitive shift, as expressed by one participant: “*I realized that even though the topics were complex, I was able to follow and learn from them.*” Such statements indicate self-efficacy and metacognitive awareness, which are critical components of higher-order scientific thinking (Kim & Reeves, 2007).

Tabel 2. Students' Progress

Learning Indicator	Classroom Evidence (Conversation/Presentation/Worksheet)	% of Students Who Achieved
Understanding of basic biotechnology concepts	"I realized that even though the topics were complex, I was able to follow and learn from them."	85%
Familiarity with bioinformatics tools (e.g., protein modelling, coding)	Students successfully identified proteins using bioinformatics software during group activity.	72%
Application of science to community/environmental issues	"I felt empathy when I saw how damaged the rivers were, since the community relies on them for water."	78%
Collaboration and group problem-solving	Students brainstormed solutions to water pollution and presented a project against plastic waste.	90%
Development of responsibility as science learners	"This project expanded my learning area as a science learner—that there was more to study and explore."	82%

Students' Progress in Biotechnology and Bioinformatics Class Based on Background and Classroom Performance

Students in this study came from different provinces and socio-economic backgrounds, bringing with them distinct local wisdom and environmental experiences. In the first session, an ethnoscience approach was used to ground their scientific inquiry in familiar cultural and ecological contexts. Through discussions of local cases, such as the condition of rivers, soil degradation, and the use of herbal plants, students were encouraged to identify community issues and connect them to biotechnology concepts.

Ethnoscience enables learners to see science through the lens of their cultural heritage, fostering meaningful connections between scientific inquiry and lived experiences (Aikenhead & Ogawa, 2007). In this course, the use of NCBI, RBS, Replit, and AI-powered applications provided students with access to advanced tools, while the ethnoscience framework ensured that technological exploration remained socially and environmentally rooted. This aligns with Cajete's (2015) assertion that science learning grounded in community experience nurtures not only knowledge but also ethical awareness and responsibility.

The second and third sessions emphasized design thinking and digital prototyping using AI and bioinformatics tools. Initially, students expressed difficulty navigating coding environments and modeling software. However, as the sessions progressed, they began to enjoy the process, demonstrating increased confidence and curiosity. They developed 2D conceptual designs of enzymes, apps, and prototypes intended to address real community problems such as water pollution and plastic waste. These findings resonate with Holmes et al.'s (2019) argument that AI integration in education enhances students' creative and analytical capacities, especially when tasks are authentic and socially relevant.

A strong affective theme emerged from the students' reflections. Many expressed empathy toward environmental issues: "*I felt empathy when I saw how damaged the rivers were, since the community relies on them for water.*" Through group-based inquiry and collaborative design, they developed a sense of social responsibility and interdependence.

The high rate (90%) of students achieving collaboration indicators underscores the importance of project-based and community-linked science learning. Consistent with Prensky (2010) and Tan and So (2019), the integration of technology-driven projects enhanced both collaboration and values formation, positioning students as active agents of change rather than passive recipients of knowledge.

Notably, the culminating stage—where projects were showcased internationally—served as an empowering experience. Two projects were presented at the *International Children's Conference*, three at the *Global Innovation Field Trip*, and one project won the *Invent Future Global Innovation Challenge*, representing the Philippines at the *Innovation Exchange Singapore*. Students reported increased confidence, pride, and scientific identity, affirming Timmis et al.'s (2017) observation that digital and project-based learning environments can strengthen learners' sense of belonging within the scientific community.

The integration of ethnoscience, AI, and bioinformatics demonstrates a holistic approach that combines technical mastery, cultural grounding, and moral engagement. Students not only learned how to use tools and design biotechnological solutions but also understood *why* these solutions matter to their communities. The development of empathy, collaboration, and scientific responsibility mirrors the broader goal of values-based science education (Timmis et al., 2017; Cajete, 2015).

Such outcomes suggest that blending *local wisdom* with *global technology* can nurture compassionate innovation—a form of learning that equips students with the competence and conscience needed to address real-world challenges in science and society.

Conclusion

The students' perception of including AI and bioinformatics in biotechnology began with an overwhelming understanding of protein modelling, coding, and problem identification, but the students were excited to continue the work and completed the tasks. In the creation process, they were prototyping the project through AI and found it meaningful for society. The reflection shows concern, social responsibility, and empathy toward the community. all the hard work had been showcased in international events such as IKC, IFGIC, IESG, and GYIS. The project went beyond technical learning, encouraging them to bring the best version of themselves to contribute to society.

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CONTEMPLATIVE DISCERNMENT IN A DIGITAL AGE: IGNATIAN PEDAGOGY AND THE PROMISE OF AI-MEDIATED EDUCATION

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Received: 19 November 2025; Accepted: 20 November 2025

Abstract

This article investigates how Ignatian Pedagogy can inform and transform the use of artificial intelligence (AI) in education, with the aim of promoting human dignity, ethical discernment, and ecological sustainability. The research objectives are threefold: (1) to explore the compatibility between the Ignatian Pedagogical Paradigm (IPP) and AI-mediated learning environments; (2) to identify pedagogical risks and ethical concerns arising from AI integration; and (3) to propose a model that aligns AI-supported practices with Ignatian educational values. The study employs a qualitative, conceptual research method through critical analysis of literature on Ignatian pedagogy, AI ethics, and educational innovation, complemented by contextual reflection based on the Indonesian educational landscape and the mission of Sanata Dharma University. The findings suggest that while AI offers pedagogical enhancements, it also requires frameworks that preserve relationality, reflection, and human formation. The article proposes a hybrid Ignatian-AI model structured around the IPP's five dimensions—context, experience, reflection, action, and evaluation—each critically examined for its AI-compatible applications. The article concludes that Jesuit education can lead the way in developing ethically grounded, spiritually aware, and contextually sensitive approaches to AI-mediated education.

Keywords: artificial intelligence, ethical formation, Ignatian pedagogy, Jesuit education, reflective discernment

Introduction

Artificial intelligence (AI) is profoundly transforming global education by enhancing learning environments through various innovative tools. The integration of AI in education promotes digital transformation and presents opportunities for more personalized, inclusive, and efficient educational systems (Ersoy, 2025). AI tools, such as adaptive learning platforms and intelligent tutoring systems, are reshaping traditional educational practices by providing personalized learning experiences, enhancing student engagement, and offering efficient assessment mechanisms (Ou, 2024).

The use of AI-powered chatbots, like ChatGPT, has sparked considerable conversation in higher education about their potential to revolutionize teaching and learning. These tools offer unique opportunities and challenges, including implications for leadership, management, and program development in academic settings (Lin et al., 2024). Moreover, AI technologies in education support the



development of essential 21st-century skills by enhancing innovation capabilities and digital literacy among students (Wu & Zhang, 2025).

However, the integration of AI also presents challenges that need to be addressed, including data privacy concerns, algorithmic biases, and the digital divide (Ou, 2024; Ray & Ray, 2024). Ethical considerations, such as maintaining transparency, accountability, and fairness in AI algorithms, are crucial to ensure responsible AI adoption in education (Ray & Ray, 2024). Furthermore, interdisciplinary collaboration among stakeholders is essential to align AI systems with educational goals and human-centered values, providing a framework for inclusive and equitable educational environments (Ersoy, 2025).

AI's transformative role in education is highlighted by its ability to optimize educational processes through cognitive development and personalized learning. It helps institutions unlock new opportunities for efficiency and accessibility, although ethical concerns must be addressed (Imran et al., 2024). By promoting responsible AI use, educational institutions can better support student success and address challenges related to AI integration, such as bias and ethical transparency (Kaur et al., 2024).

To maximize the potential of AI in education, stakeholders must focus on creating inclusive AI ecosystems, addressing bias, data privacy, and ensuring fair and equitable education standards in line with global standards and evidence-based practices (Ersoy, 2025). This strategic integration of AI into education systems promises to transform teaching methodologies, student engagement, and administrative processes significantly, driving educational advancement in the digital age (Chetry, 2024).

While AI promises efficiency, personalization, and expanded access, it also raises profound ethical, pedagogical, and anthropological questions: What happens to the relational core of teaching? How is moral and spiritual formation impacted? Can AI support rather than undermine the mission of forming holistic, ethical, and compassionate persons?

In Jesuit and Catholic education, these questions are particularly urgent. Rooted in a 500-year-old tradition of humanistic education, Ignatian pedagogy emphasizes not only academic excellence but also ethical discernment, spiritual reflection, and service to others. This article explores how Ignatian pedagogy can inform, shape, and critique the integration of AI in education, proposing a human-centered approach that places technology at the service of integral formation. In the context of Indonesian education reforms, such as the *Kurikulum Merdeka*, and inspired by the legacy of Prof. Dr. Nicolaus Drijarkara, SJ, the Faculty of Teacher Training and Education (FKIP) at Sanata Dharma University offers a fertile ground for exploring how Ignatian values can inform digital transformation.

Method

This study employs a qualitative, conceptual research design rooted in theological inquiry and educational philosophy. The research seeks to integrate insights from Ignatian Pedagogy, AI ethics, and educational innovation through interpretive and critical analysis. It follows a hermeneutical-analytical approach, emphasizing understanding (*verstehen*) over measurement, and reflection over prediction.

Research Design

The article adopts a conceptual-theoretical framework rather than an empirical design. It synthesizes existing scholarship on Ignatian pedagogy and artificial intelligence in education to articulate an integrative model of human–AI interaction within Jesuit educational contexts. The research builds on theological anthropology and educational ethics to interpret the implications of AI for human formation and discernment.

Data Sources and Materials

Data for this study consist of secondary sources, including peer-reviewed journal articles, official Church documents, and policy statements relevant to Jesuit and Catholic education. The primary sources include:

- Ignatian Pedagogy: A Practical Approach (ICAJE, 1993), serving as the foundational pedagogical framework.
- Papal encyclicals such as *Laudato Si'* (2015) and *Laudate Deum* (2023), which inform the study's ecological and ethical dimensions.
- Recent scholarly works on AI ethics, digital education, and Ignatian spirituality published between 2020 and 2025, retrieved from Scopus and Web of Science databases.

Analytical Procedure

The analysis proceeds in three interpretive stages:

1. Descriptive synthesis – mapping current literature on AI-mediated education and identifying key pedagogical opportunities and risks.
2. Critical correlation – interpreting these findings through the lens of Ignatian Pedagogy, emphasizing the five IPP elements (context, experience, reflection, action, evaluation).
3. Constructive proposal – developing a hybrid Ignatian–AI model that aligns technological innovation with human formation, ethical discernment, and ecological sustainability.

This process is guided by Ignatian discernment as a methodological stance—an iterative movement of observation, reflection, and action oriented toward integral human growth.

Contextual Reflection

The research situates its analysis within the Indonesian higher education context, particularly the mission of Sanata Dharma University, a Jesuit institution committed to forming “men and women for others.” The contextual reflection explores how national education reforms (e.g., *Kurikulum Merdeka*) interact with Ignatian principles and digital transformation.

Validity and Reflexivity

To ensure scholarly rigor, the study employs triangulation of sources (educational theory, theological texts, and policy documents) and reflexive interpretation, acknowledging the researcher's positionality within Catholic moral theology and Jesuit education. The conclusions are thus not universal generalizations but contextually grounded insights intended to guide future pedagogical practice and institutional policy.

Findings and Discussion

Ignatian Pedagogy: A Humanizing Framework

The Ignatian Pedagogical Paradigm (IPP), as articulated by the International Commission on the Apostolate of Jesuit Education (ICAJE, 1993), is grounded in the Spiritual Exercises of St. Ignatius of Loyola. It identifies five interrelated elements that form the core of this pedagogical framework:

1. **Context:** Understanding the specific circumstances and environments in which the learner is situated. This involves considering factors such as learners' backgrounds, experiences, and the socio-cultural dynamics that influence the learning process.
2. **Experience:** Engaging students in activities that provide direct experiences and facilitate learning. This element focuses on the role of active participation and experiential learning in helping students grasp new concepts and ideas.
3. **Reflection:** Encouraging students to reflect on their experiences and learn from them. This reflective practice is critical for fostering deeper understanding, personal growth, and the ability to apply knowledge in different contexts.
4. **Action:** Guiding students to take informed and responsible actions based on their learning and reflections. This element emphasizes the importance of applying insights gained from personal reflection and experiences to real-world situations.
5. **Evaluation:** Assessing the learning process and outcomes to ensure that educational objectives are met and to identify areas for improvement. Evaluation is both a formative and summative process aimed at enhancing learning effectiveness and personal development.

These elements are designed to work in harmony, offering a comprehensive approach to education that is holistic, context-sensitive, and deeply connected to the individual's personal and spiritual development.

This paradigm, shaped by the principle of *cura personalis* (care for the whole person), affirms education as a transformative journey of becoming fully human and oriented toward the common good. The IPP is not a static method but a dynamic approach adaptable to new cultural and technological realities, including ecological consciousness as emphasized in *Laudato Si'* and *Laudate Deum*.

Mapping AI-Mediated Education: Opportunities and Risks

Opportunities

Artificial Intelligence (AI) is revolutionizing the educational landscape through various applications such as personalized learning platforms, automated feedback systems, learning analytics, AI tutors, and administrative automation. These applications demonstrate significant potential for enhancing educational experiences, improving outcomes, and increasing educational efficiency.

AI in education encompasses a range of applications:

1. **Personalized Learning Platforms:** AI-driven personalized learning platforms harness machine learning algorithms to tailor educational experiences to individual learners' needs. By analyzing performance data, these systems adapt content delivery to suit diverse learning styles, thereby promoting a more inclusive and engaging environment (Nuong Deri et al.,

2024). The integration of AI in educational systems allows students to learn at their own pace, enhancing engagement and outcomes (Osman & Ahmed, 2024).

2. **Automated Feedback and Assessment Tools:** AI can automate feedback and assessment, providing real-time personalized feedback, identifying areas for student improvement, and contributing to more nuanced grading systems (Vashishth et al., 2024). These tools not only streamline the assessment process but also free up educators' time, allowing them to focus more on personalized instruction (Osman & Ahmed, 2024).
3. **Learning Analytics and Behavior Prediction:** Leveraging learning analytics, AI gathers, analyzes, and predicts student behavior, thereby supporting personalized feedback and learning approaches (Vashishth et al., 2024). This involves analyzing vast amounts of data to provide actionable insights for educators, helping to tailor interventions and optimize educational outcomes (Akavova et al., 2023).
4. **AI Tutors and Conversational Agents:** Generative AI and intelligent tutoring systems use language models to create adaptive and interactive learning environments. These systems offer features like automated question generation and customized feedback, aligning closely with individual student needs (Maity & Deroy, 2024). AI tutors enhance engagement and educational accessibility, promising to create more effective learning experiences (Jane et al., 2024).
5. **Administrative Task Automation:** AI significantly optimizes administrative processes within educational institutions, such as admissions, scheduling, and resource allocation. By automating these tasks, AI reduces workloads while enhancing operational efficiency and cost-effectiveness (Nuong Deri et al., 2024). This streamlining allows educational institutions to allocate more resources toward instructional quality and student support.

Although these AI applications present significant opportunities, they must be implemented with consideration for ethical issues such as data privacy, bias in algorithms, and the digital divide (Ou, 2024). Furthermore, ongoing innovation, collaboration, and teacher training are crucial to ensuring these technologies are effectively integrated and maximize their impact on the educational landscape (Mahmoud & Sørensen, 2024). Thus, AI's role in education is multifaceted, significantly transforming how students learn and how educational systems operate. By continuing to evolve these technologies, education systems can create more personalized, efficient, and inclusive learning experiences that meet the needs of diverse learners.

Risks

The integration of Artificial Intelligence (AI) in education has transformative potential, enhancing efficiency, engagement, and scalability, but it also raises several critical concerns. Scholars have identified key risks related to dehumanization, bias and inequity, data surveillance, instrumentalism, and ecological impact:

1. **Dehumanization: Reduced Teacher-Student Interaction:** The increasing reliance on AI in education may lead to reduced human interaction, potentially impacting the relational dynamic between teachers and students.

As AI tools take over tasks traditionally handled by educators, there's a risk of diminishing the human elements of teaching, which are essential for fostering empathy and understanding in learning environments (Abdelaal & Al Sawy, 2024; Bai, 2024).

2. **Bias and Inequity: Algorithmic Discrimination and Access Gaps:** AI systems in education can inadvertently perpetuate existing biases present in their training data. This can lead to unfair treatment of certain demographic groups, undermining the fairness and inclusivity of educational programs. Efforts must be made to ensure that AI systems are fair and equitable, involving diverse datasets and bias mitigation strategies (Chinta et al., 2024; Mishra et al., 2024).
3. **Data Surveillance: Ethical Concerns About Privacy and Autonomy:** The pervasive use of AI in educational settings raises significant concerns about data privacy. The surveillance required for AI analytics can infringe on students' privacy and autonomy, necessitating strong ethical frameworks to protect personal data and maintain transparency (Anshari et al., 2022; Khan et al., 2025). Policies prioritizing data protection and ethical decision-making are essential to maintaining trust and protecting individual rights (Kunz & Wirtz, 2023).
4. **Instrumentalism: Learning Reduced to Measurable Outcomes:** Education facilitated by AI may focus excessively on quantifiable outcomes, sidelining holistic learning approaches that encompass critical thinking, creativity, and emotional intelligence. It is crucial to balance AI-driven data insights with pedagogical goals that consider the broader development of students (Gupta, 2023).
5. **Ecological Impact: Energy Consumption and Sustainability:** AI technologies consume substantial amounts of energy and resources, raising sustainability issues. The environmental footprint of AI systems needs careful consideration, with efforts directed towards minimizing energy use and exploring green AI solutions to ensure sustainable educational innovations (Khan et al., 2025).

Addressing these challenges requires a collaborative, interdisciplinary approach that integrates ethical considerations, diverse stakeholder involvement, and transparent governance. Balancing the opportunities and risks associated with AI in education is essential to ensuring its equitable and effective integration into learning environments. These challenges highlight the need for a robust ethical and pedagogical compass. Ignatian pedagogy can offer such a compass, rooted in anthropological, theological, and ecological insights.

Ignatian Pedagogy and AI: Integrative Possibilities

Context: From Data to Discernment

AI systems can map student behaviors and learning profiles. Yet Ignatian pedagogy demands more: an understanding of the learner's existential and spiritual context. Teachers must read not only data but also desire, struggle, and potential. In Indonesia, this includes recognizing disparities in access to technology and forming educators capable of interpreting socio-cultural nuances.

Experience: Augmenting, Not Replacing

While AI can simulate real-world experiences through VR or gamification, authentic formation requires personal encounter, dialogue, and affective engagement. AI may assist but should not replace embodied, relational learning. At Sanata Dharma University, reflective fieldwork, spiritual retreats, and service-learning projects offer immersive learning experiences that can be complemented—not substituted—by AI tools.

Reflection: Depth Over Speed

Ignatian reflection invites students to internalize learning through prayer, journaling, and spiritual conversation. AI may provide prompts or feedback, but cannot replicate the grace of discernment. Reflection in a Jesuit context is more than cognition; it is transformative insight. Educators must be trained to guide such reflection, drawing on Lonergan's notion of intellectual conversion and Driyarkara's philosophy of humanization.

Action: For the Common Good

AI-enabled learners should be equipped to act ethically and justly. Ignatian pedagogy forms “persons for others,” which entails critical consciousness and moral responsibility. Projects supported by AI must be oriented toward solidarity, ecology, and justice. For instance, using AI to design community mapping or ecological monitoring tools aligns technological innovation with Catholic social teaching.

Evaluation: Beyond Analytics

While AI can offer dashboards and metrics, Ignatian evaluation includes moral, emotional, and spiritual growth. Teachers must interpret data through a pastoral and formative lens, considering the learner's journey toward personal vocation and social responsibility.

Human-AI Ignatian Model: Charting the Way Forward

The following table proposes an integrative model.

Table 1. Integrative Model

IPP Element	AI-Supported Practice	Ignatian Integration
Context	Learning analytics	Personal interviews, spiritual direction, attention to social inequities
Experience	Simulated environments	Real-world immersion, service-learning, ecological action projects
Reflection	AI journaling prompts	Guided examen, communal discernment, spiritual accompaniment
Action	Project-based learning tools	Ethics labs, justice projects, digital stewardship programs
Evaluation	Real-time feedback	Narrative assessment, pastoral accompaniment, growth in virtues

Implications for Teacher Formation and Institutional Strategy

To integrate ethics, Ignatian discernment, and ecological awareness effectively into Jesuit teacher training programs, consider the following structured approach.

- a. **Curriculum Development:**
 - **Ethics Education:** Develop comprehensive courses focusing on moral reasoning and ethical decision-making in educational contexts (Maxwell et al., 2016; Warnick & Silverman, 2011).
 - **Ignatian Discernment:** Include modules dedicated to the processes of reflection and discernment rooted in Ignatian tradition, helping teachers align actions with personal and community values.
 - **Ecological Awareness:** Integrate environmental education to promote ecological sustainability and align with Jesuit principles of care for creation (Rowston et al., 2019).
- b. **Pedagogical Strategies:**
 - **Experiential Learning:** Utilize case studies presenting ethical dilemmas that encourage students to apply Ignatian reflective practices.
 - **Collaborative Projects:** Design projects promoting environmental stewardship, engaging students with local community sustainability efforts.
- c. **Professional Development:**
 - **Workshops and Seminars:** Offer continuous training on ethics, Ignatian spirituality, and ecological issues to enhance teaching and reflection (Boon, 2011).
 - **Mentorship Programs:** Establish mentorship opportunities where experienced educators guide new teachers, fostering a strong community of reflective practice.
- d. **Assessment and Feedback:**
 - **Reflective Journals:** Encourage students to maintain journals documenting experiences related to ethics and ecological issues.
 - **Feedback Mechanisms:** Implement systems to receive student and stakeholder feedback on the curriculum's effectiveness and impact (Sullivan et al., 2020).
- e. **Community Engagement:**
 - **Service Learning:** Partner with local organizations for students to gain hands-on experience in addressing social and environmental challenges.
 - **Partnerships:** Establish collaborations with ecological and ethical institutions to broaden learning opportunities and global citizenship.

Integrating these elements will create a holistic educational environment in Jesuit institutions, equipping future educators with the skills to be reflective and responsible leaders within their communities.

To ensure digital equity in infrastructure and access, the following policy recommendations are essential.

a. Investment in Infrastructure

Governments and educational institutions should invest in the development and expansion of digital infrastructure, particularly in underserved and rural areas. This involves providing high-speed internet access and modern technological tools to ensure all students have equal access to digital learning environments.

b. Public-Private Partnerships

Formulate partnerships between the public sector and tech companies to leverage resources and expertise in expanding digital infrastructure. Such collaborations can enhance the reach and efficiency of digital services in education.

c. Affordable Access:

Implement policies that promote affordable internet and digital device plans for students and educators, ensuring that financial constraints do not hinder access to education.

d. Comprehensive Digital Literacy Programs:

Develop digital literacy programs aimed at students, teachers, and parents to empower them with the necessary skills to effectively engage with digital platforms. These programs should focus on the use of digital tools, online safety, and critical thinking in digital environments.

e. Equitable Resource Distribution:

Ensure the equitable distribution of digital resources and educational content across all schools, with a focus on reducing disparities between urban and rural schools. This can be achieved through effective policy measures and resource allocation strategies.

f. Monitoring and Evaluation:

Establish a framework for the continuous monitoring and evaluation of digital equity initiatives, allowing for the identification of gaps and areas for improvement. This should include feedback mechanisms involving stakeholders such as students, educators, and parents.

These strategies, aimed at bolstering digital equity, can significantly contribute to a more inclusive and accessible educational environment for all learners (Jenkins et al., 1998).

To address the policy recommendations for upholding *cura personalis* in digital learning environments, promoting sustainability in tech choices, and encouraging global collaboration among Jesuit and Catholic universities for curriculum co-creation, consider the following strategies.

Upholding Cura Personalis in Digital Learning Environments

'Cura personalis,' a Jesuit principle that emphasizes care for the whole person, can be integrated into digital learning by prioritizing user-friendly, culturally appropriate digital designs and fostering supportive educational environments (Wilson et al., 2024). This approach aligns with creating personalized learning paths that respect each student's unique context and needs, ultimately enhancing engagement and educational success (Wang & Si, 2024).

Promoting Sustainability and Ecological Responsibility in Tech Choices

In the realm of sustainable tech, green technology innovation plays a crucial role. Research highlights the importance of incorporating environmental, social, and governance (ESG) criteria into business and technology practices to enhance sustainability (Zhang & Jin, 2022). Strategies include investing in green technologies and collaborating with stakeholders to create sustainable corporate practices (Huang et al., 2025; Maldonado-Guzmán, 2024).

Encouraging Global Collaboration Among Jesuit and Catholic Universities for Curriculum Co-Creation

Collaboration across institutions, particularly among Jesuit and Catholic universities, can drive curriculum innovation and inclusivity. Emphasizing equitable partnerships can foster more profound systemic rebalancing and create an inclusive global academic ecosystem (Aboderin et al., 2023). Such collaborations are pivotal in leveraging diverse insights and resources, ensuring curricula are comprehensive and culturally relevant, and facilitating the co-creation of knowledge (Hustad, 2004).

In implementing these recommendations, universities and policymakers must consider these research insights to develop effective, inclusive, and sustainable educational environments. By doing so, they promote equity, respect, and global connectivity across educational systems.

Conclusion

AI will continue to shape education, but it need not dictate its meaning. Through Ignatian pedagogy, Jesuit education can humanize technology, safeguard relationality, and promote a vision of education rooted in justice, discernment, and the love of God. The challenges of digital transformation are real, especially in contexts like Indonesia, where disparities persist, but so are the opportunities. In a world of smart machines, the task of forming wise, compassionate, and discerning humans is more urgent than ever. As Pope Francis reminds us in *Laudato Si*, education must cultivate a spirituality of communion with one another, with creation, and with the divine.

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PRACTICALITY OF PROBLEM-BASED MATHEMATICS WORKSHEETS ASSISTED BY GEOGEBRA TO ENHANCE STUDENTS' MATHEMATICAL CONCEPTUAL UNDERSTANDING

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Received: 30 September 2025; Accepted: 25 November 2025

Abstract

Problem-Based Learning (PBL) is an instructional model that uses authentic problems. Integrating PBL with GeoGebra promotes active engagement and exploration of mathematical concepts. It also helps develop creativity and supports the use of critical thinking skills in problem solving. This combined approach leads to a more comprehensive understanding of mathematics. Effective implementation requires a structured strategy. Instructional tools must be accessible to both teachers and students throughout the process. This study aims to identify and describe the practicality of student worksheets (LKPD). The research method used in this study is Research and Development (R&D), following the ADDIE model. Although the ADDIE model consists of 5 stages, this research only consists of 3 stages, namely the analysis, design stages and development stages, as it aims to describe the practicality of the instructional tools. Practicality was carried out by teachers and students. The results showed that the device, on average, received a positive response from students and teachers. These instructional tools are designed for Grade XI senior high school students. The practicality results indicate that LKPD also received an excellent rating across all assessed aspects. Therefore, the LKPD is deemed suitable to improve the mathematical concept understanding of students.

Keywords: linear program, mathematical conceptual understanding, problem-based learning, worksheets

Introduction

Mathematics serves as a foundational discipline that underpins the progress of various scientific fields. Mathematics is a discipline that serves as a tool for solving various problems encountered in daily life. Its development has been closely linked to other sciences, which rely on mathematical concepts to facilitate their advancement. Along with the advancement of science and technology, mathematics plays a crucial role in fostering systematic, critical, and logical thinking. Therefore, it is expected to be one of the most accessible and understandable subjects for students (Ernest et al, 1991; Resnick & Ford, 2012). According to Permendiknas No 22 of 2006 (Kementerian Pendidikan Nasional Republik Indonesia, 2006), the aim of learning mathematics is for students to grasp mathematical concepts, explain the relationships between them, and apply them or the relevant algorithms effectively, accurately, and efficiently in problem-solving situations.



One important aspect of achieving this goal is students' conceptual understanding, which refers to their ability to master and meaningfully apply various mathematical concepts (Nurdin et al., 2019; Suraji et al., 2018; Zetriuslita et al., 2025). This means that students not only understand the concepts being studied but can also express them in different, easily understandable forms (Septiadi & Wahidah, 2022). Furthermore, there are several indicators of conceptual understanding that students are expected to master: 1) restating a concept; 2) classifying specific characteristics; 3) providing examples; 4) representing concepts; and 5) applying concepts to solve problems (Faizah, 2019). Despite the recognized importance of conceptual understanding, recent assessments indicate a gap in students' actual performance, as shown in the PISA results. The PISA assessment emphasizes reading, writing, and mathematics accuracy, focusing on students' competencies and skills that can be applied in everyday life (OECD, 2009). The components of the PISA questions require the ability to reason, understand mathematical concepts, make estimations, and then express these in numerical form while performing calculations mentally (OECD, 2013), where Indonesia ranked 73rd out of 80 participating countries in the mathematics category, with an average score of 379. In contrast, China ranked first with an average score of 591 (Wulaningsih et al., 2021). This indicates that students in Indonesia struggle with mathematics. The low mathematical proficiency among students can be attributed to various internal and external factors. The external factors are the choice of learning tools and the strategies used in educational materials.

Learning tools guide teachers in conducting lessons and act as benchmarks for implementing the learning process (Angraini et al., 2021). According to Ariawan and Putri (2020), learning tools are resources that teachers and students can utilize during teaching and learning. One of the learning tools focused on in this research is worksheets. According to Wati & Haryati (2017), the integration of worksheets into the learning process enables students to demonstrate their abilities and skills while fostering the development of critical thinking through activities such as inquiry, hypothesis generation, and logical reasoning. Worksheets provide a series of activities in the form of theoretical and practical steps that facilitate independent learning and help students understand the material (Aprilianti & Astuti, 2020). Furthermore, the use of worksheets contributes to an effective learning process, stimulates students' interest, fosters curiosity to enhance motivation, and improves their problem-solving ability (Pratiwi, 2021). Based on the results from the researcher's interview with a mathematics teacher at the school revealed several issues regarding the current worksheets. These issues include: 1) There is no evidence that worksheets that incorporate GeoGebra software technology are being utilized at the school. 3) The available worksheets contain only a summary of the material and practice questions, without any completion guidance provided. 4) The existing worksheets are limited to a few topics and are infrequently used due to time constraints and the excessive time required to complete them.

The issues surrounding worksheets have hindered students' understanding of mathematical concepts. Therefore, it is essential to implement a suitable learning model to assist students in grasping these concepts. One effective alternative is the PBL model. According to Saleh et al (2020), problem-based learning is an instructional approach in which students engage with real problems and apply

scientific methods to develop solutions. Worksheets can be designed to incorporate the principles of PBL. This model encourages students to "learn how to learn" by collaborating in groups to find solutions to real-life challenges (Ariawan & Putri, 2020). Problem-based learning stimulates students to face and solve problems. As Kotto et al. (2022) showed, this approach requires students to think critically, reason, communicate, seek, analyze facts, and draw conclusions. To facilitate these skills, teachers present relevant problems, encouraging reasoning through group discussions. In this way, PBL lets students demonstrate critical thinking, reasoning, and share ideas. Furthermore, according to Alfiah et al. (2021), problem-based learning starts with contextual problems, centers on students, builds understanding, and fosters discussion. The advantages of the PBL model include making learning more meaningful, fostering student independence, enhancing students' creative thinking, and improving their understanding of concepts (Sinaga et al., 2021). Additionally, PBL can actively contribute to improving learning outcomes and students' comprehension of concepts and attitudes towards learning (Zetriuslita & Andrian, 2019).

While the PBL model has the potential to enhance students' understanding of mathematical concepts, its effectiveness has certain limitations. Therefore, it is crucial to improve this approach by incorporating innovative media, such as GeoGebra software, as learning resources. GeoGebra is a tool that enables users to create simple representations of mathematical objects, making it easier to discover, solve, and visualize ideas they already have (Zetriuslita et al., 2021). Using PBL models supported by computer technology actively engages students and allows them to explore various mathematical concepts. This method promotes creativity and integrates critical thinking skills, enabling students to grasp the material independently. Furthermore, GeoGebra is particularly effective for visualizing and demonstrating mathematical concepts, especially in geometry and algebra (Zetriuslita et al., 2020; Nur'aini et al., 2017).

Consequently, the use of GeoGebra can facilitate understanding of mathematical concepts, as it supports the application of indicators of comprehension, including the presentation of concepts in different mathematical forms, such as graphs and tables. Supporting this, research conducted by Wahyuni and Rahmadhani (2020) indicates that learning mathematics using the GeoGebra-assisted PBL model is more engaging than the standard PBL model without GeoGebra. This approach enhances students' understanding of mathematical concepts. The researcher chose to focus on linear programming, as this material highlights the concept of optimizing values, which can be effectively illustrated using GeoGebra software. Furthermore, linear programming aligns well with the indicators for assessing the ability to understand mathematical concepts, which can be promoted through PBL models alongside GeoGebra. Based on the description above, the development of problem-based learning (PBL) model devices assisted by GeoGebra plays a crucial role in enhancing students' understanding of mathematical concepts. The purpose of this study is to evaluate the practicality of student worksheets based on PBL models supported by GeoGebra, specifically aimed at facilitating students' understanding of mathematical concepts related to linear program.

Method

This research is a development study that aims to produce and test the practicality of worksheets with a problem-based learning model assisted by GeoGebra to enhance the understanding of mathematical concepts. The development used in this study is an ADDIE model consisting of analysis, design, development, implementation, and evaluation (Hawa, 2021). Educational practitioners develop ADDIE models in developing training or learning program tools and infrastructure that are effective, dynamic, and support the learning process (Branch, 2009; Molenda, 2003; Junaedi, 2019). In this research, it only reached 4 stages: the analysis stages, design stages and development stages, and implementation stages. The analysis stage starts with analysis, including problem analysis of worksheets and need analysis of curriculum, competencies, and indicators. The design stage aims to produce an initial draft of worksheets, teacher, and student response questionnaires. At the development stage, validation is carried out with a very valid category, and in this study, furthermore, the validity of student worksheets was tested on a limited class XI SMAN 1 Bangkinang to determine the effectiveness and practicality. This research is limited only to the development stage, where this study only discusses the practicality of the worksheets.

The practicality of the developed student worksheets was evaluated based on the results of the student response questionnaire and observations of the learning implementation. The data collection technique was carried out using a teacher and student response questionnaire. The data analysis technique used to measure the practicality of worksheet use involves tabulating results. The criteria consist of very practical, practical, practical enough, less practical, and not practical (Riduwan & Akdon, 2013) as follows:

$$P = \frac{\Sigma f}{N} \times 100\%$$

The results obtained are interpreted using the criteria according to the modification Riduwan & Akdon (2013), as in the following table.

Table 1. Practical Criteria

Score (%)	Validity Level
$80 < P \leq 100$	Very Practical
$60 < P \leq 80$	Practical
$40 < P \leq 60$	Practical enough
$20 < P \leq 40$	Less Practical
$0 < P \leq 20$	Not Practical

Findings and Discussion

The practicality of the student worksheets that have been developed was obtained from the student response questionnaire. The practicality test of the student worksheets was carried out on 30 students in a class. The results of the questionnaire analysis of the practicality test can be seen in Table 2.

Table 2. Average Results of Student Questionnaire on the Worksheet

No.	Indicators	Percentage of Worksheets' Achievement			Average	Category
		1	2	3		
1	This worksheet helps me solve mathematical problems presented as real-life word problems	83,33	87,00	90,38	86,90	Very Practical
2	This worksheet facilitates my understanding of the material being studied	81,48	82,00	88,48	83,98	Very Practical
3	The instructions for using GeoGebra in this worksheet are clearly understandable	86,11	89,00	91,34	88,81	Very Practical
4	The combination of solving problems through conventional methods and GeoGebra enables me to better understand the concept of linear programming	85,18	86,00	84,61	85,26	Very Practical
5	The integration of GeoGebra software in this student worksheet increases my motivation and enthusiasm for learning	83,33	83,00	88,46	84,93	Very Practical
6	The language used in the student worksheets is easily comprehensible.	83,33	85,00	87,50	85,27	Practical
7	The practice questions in this worksheet are aligned with the material presented	89,81	86,00	93,26	89,69	Very Practical
8	The dimensions of the images, the font, and the color scheme in this student worksheet are appropriate, which facilitates readability	86,11	86,00	91,34	87,81	Very Practical
9	The color scheme and design of the worksheets are appropriate, which increases my interest in learning and practicing the problems	87,96	90,00	93,26	90,40	Very Practical
10	The student worksheet has an appealing design that encourages reading	86,11	86,00	87,50	86,53	Very Practical
11	The allocated time is adequate for completing the	81,48	86,00	88,46	85,31	Very Practical

	questions in the student worksheets						
12	The use of GeoGebra software helps me check the correct answers to linear programming problems	88,89	88,00	87,50	88,13		Very Practical
	Average (%)				86,91		Very Practical

Table 3. Results of Questionnaire Analysis of Student Responses to LKPD

Percentage Validity (%)			Average Validity (%)	Validity Level
Pert-1	Pert-2	Pert-3		
85.26	86.16	89.34	86.92	Very Practical
Total Average (%)			86.92	Very Practical

Based on the results of the study, as shown in Tables 2 and 3, the worksheets using the PBL model assisted by GeoGebra to enhance mathematical conceptual understanding received positive responses from students. This can be seen from the average results of the responses that give “very practical” for each indicator. This indicates that students are more motivated to learn with the PBL model integrated with GeoGebra. This is in line with research conducted by Asmiati et al. (2020), which shows that by developing learning tools that include student worksheets with the PBL model assisted by GeoGebra, the practicality results from the teacher response questionnaires form were very good, indicating that the learning tools are practical to be implemented in schools. Further research indicates that the student worksheet assisted by GeoGebra demonstrates practicality, as evidenced by data from student, teacher questionnaire form, and observation sheets (Nurlisna et al, 2019). Other research findings indicate that the development of GeoGebra-based worksheets using the PBL model, as shown in the practicality test, received positive responses from students. They found the worksheets engaging, easy to understand, and encouraging more active participation in the learning process (Astuti et al., 2025). Based on the above findings as well as previous studies, it can be concluded that the student worksheet is practical and feasible to be implemented in schools.

Conclusion

Based on the analysis of the research data, the practicality results from the students' response questionnaire are highly positive. The student worksheets with the Problem-Based Learning model assisted by GeoGebra are very practical in enhancing mathematical conceptual understanding abilities. The student worksheets have been demonstrated to be valid and practical across all evaluation aspects. These student worksheets are suitable for high school students in XI in linear program subjects. However, this research only involved practicality from student response questionnaires and validation from experts in another research.

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CHEMISTRY EDUCATION STUDENTS' DIFFICULTIES IN UNDERSTANDING ENGLISH LITERATURE

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Received: 17 November 2025; Accepted: 25 November 2025

Abstract

Chemistry education students often face challenges in comprehending English-language literature, although most chemistry literature is published in English. These difficulties lead to reluctance in reading, as the material is considered complex and time-consuming, potentially hindering optimal development of scientific knowledge. This literature review analyzes seven journal articles to identify the difficulties, contributing factors, and impacts experienced by chemistry education students in understanding English-language literature. The results indicate that students struggle with grasping main ideas, implied information, and vocabulary. The implementation of basic English courses has been shown to improve students' abilities, as evidenced by enhanced vocabulary, reading, and writing skills, and positive responses to effective, easy-to-understand, and useful teaching methods. Therefore, while challenges remain, learning basic English plays a crucial role in enhancing chemistry education students' ability to comprehend scientific literature.

Keywords: basic English, chemistry education, English-language literature, reading comprehension, vocabulary

Introduction

In the era of globalization of science and technology, English literacy skills have become one of the essential competencies for university students, particularly in scientific fields such as chemistry. This is because most scientific literature sources, including journals, research articles, and chemistry textbooks, are written in English as the primary language of international scientific communication. Proficiency in English not only helps students understand complex chemical theories and concepts but also opens access to the latest developments in research and scientific innovation worldwide. However, in reality, not all chemistry students possess strong abilities in comprehending English-language literature. Many of them find it difficult to interpret technical terms, complex sentence structures, and the scientific context used in foreign language texts. These difficulties often lead to reluctance and disinterest in reading further, as they are perceived as time-consuming and demanding significant effort to understand the content (Mardiani et al., 2021).



The phenomenon of low interest in reading English texts has actually appeared since elementary school. Based on a study by Sari et al. (2024), it was found that 61% of students had a good interest in reading English texts, 31% were in the fair category, 4% poor, and 4% very good. This means that 4% of students had no interest in English reading because they considered it boring and difficult to understand. This condition indicates that interest in reading English-language literature remains a real challenge even from an early age, which can influence students' reading habits at the university level (Jumaroh & Aisyah, 2021). As a result, students tend to avoid English-language literature sources and prefer Indonesian references, which are relatively limited in number. By avoiding English sources, students risk losing opportunities to optimally broaden their scientific horizons. This situation can lead to weak scientific analytical skills and outdated information, which hinders the development of academic competence in chemistry (Fajri & Akmaluddin, 2018). Therefore, it is important to foster awareness and motivation among chemistry students to become more open to reading scientific literature in English. In addition, effective learning strategies and mentoring are required to help students improve their ability to read and comprehend scientific texts in English. Thus, students can become more active and confident in exploring various global scientific sources, which in turn supports the improvement of chemistry education quality at the university level (Tambunsaribu, 2022). This review is expected to provide suggestions for improving English proficiency among students in the chemical education study program, thereby supporting academic success.

Method

The method used in this study was a literature review, which is a systematic approach to identifying, analyzing, and synthesizing various scientific literature sources relevant to the research topic. This process involved several main stages. First, selecting and collecting journals, research articles, and textbooks discussing students' English literacy skills, particularly in chemistry. The literature search was conducted using the Google search engine. The keywords were chemistry education, English-language literature, reading comprehension, basic English, and vocabulary. Second, evaluating the quality and relevance of each source was done based on specific criteria such as data accuracy, publication year, and contribution to understanding the issue. Third, content analysis was conducted to identify main themes, students' difficulties, causal factors, and strategies that have been implemented to improve literacy skills; and fourth, synthesizing the analysis results to provide a comprehensive overview of the conditions, challenges, and solutions related to chemistry students' comprehension of English-language literature. Through this method, the study could present a systematic and accurate summary of the investigated phenomenon and support the development of effective learning strategies.

Findings and Discussion

The Importance of English Literacy in Chemistry Education

In the context of chemistry education, English literacy is a fundamental skill for students, as most scientific literature, including journals, research articles, and textbooks, is written in English as the primary language of international scientific communication. Proficiency in English not only facilitates students' understanding of complex chemical theories and concepts but also provides access to recent research, global scientific innovations, and the development of competencies aligned with international standards (Azamat et al., 2024). Students who can effectively read English-language literature have greater opportunities to stay updated with the latest chemistry research, compare methodologies across studies, and integrate scientific findings from different countries into their learning and research practices.

Nevertheless, in reality, many students face significant difficulties in reading English-language literature. Research shows that around 65% of chemistry education students struggle to understand technical terms and complex sentences in scientific literature, while 25% report only partial comprehension, and 10% state that they are unable to interpret English literature independently. These difficulties arise not only from limited vocabulary but also from challenges in interpreting implicit meanings, understanding conceptual relationships, and linking theories with experimental data presented in academic texts. Moreover, formal sentence structures and academic writing conventions often pose additional barriers, as students are not yet familiar with scientific grammar and international writing standards (Setyaningsih et al., 2024).

The phenomenon of low interest in reading English-language literature has also been observed since early education. Although 61% of elementary students have good English reading interest, there are still 4% who are uninterested because English texts are considered boring and difficult to understand. This condition shows that low reading habits in English-language literature have formed from an early age and may continue into higher education. Consequently, university students tend to avoid international literature sources and rely more on Indonesian references, which are relatively limited and often lack the most recent developments in chemistry research. This choice directly affects students' ability to conduct scientific analysis, evaluate data, and understand global research contexts, thereby limiting their learning quality, innovation, and academic contribution (Sari et al., 2024).

Psychological Factors and Facility Limitations in English Literacy

In addition to reading habits and language limitations, psychological factors also affect students' ability to read English-language literature. Students often experience anxiety, low self-confidence, and frustration when encountering complex scientific texts. These feelings lead to procrastination or avoidance of reading, indirectly slowing their scientific literacy development. Furthermore, limited supporting facilities such as access to paid international journals, a lack of academic guidance in reading English texts, and insufficient integration of English literature in the curriculum are also major obstacles. These factors collectively create conditions in which students' comprehension of English-language scientific

literature remains suboptimal, even though such literature constitutes the main source of modern chemical knowledge.

The difficulty in reading English-language literature directly affects students' learning patterns. They tend to avoid international literature and rely more on Indonesian references, which are limited in number and sometimes do not include the latest developments in chemistry. As a result, their analytical and evaluative abilities become restricted, and their learning motivation decreases because they feel incapable of keeping up with global academic literature (Setyaningsih et al., 2024). This condition clarifies that low English literacy is not merely a linguistic issue but also impacts learning quality, conceptual understanding, and students' critical thinking skills in chemistry.

Learning Strategies to Overcome English Literacy Challenges

To address these difficulties, various strategies have been implemented and shown positive outcomes in enhancing scientific literacy skills. One widely used approach is the development of English-language chemistry textbooks that not only present chemical material but also include technical vocabulary, grammar, and examples of scientific terminology used in context with the course material. Explained that such textbooks do not merely provide conceptual knowledge but are systematically designed to strengthen students' understanding of technical terms, scientific sentence structures, and interpretation of information in English-language literature. Students using these textbooks reportedly gain greater confidence, as they can comprehend scientific texts more effectively and recognize common writing structures and linguistic patterns used in international chemistry journals. Thus, these textbooks serve as a bridge between students' basic English proficiency and complex scientific literature, enabling them to learn to read literature more effectively and independently without relying on translation or external assistance (Oktapianti, 2022).

Moreover, the implementation of active learning models, particularly Project-Based Learning (PjBL), has proven effective in overcoming English literacy challenges. It is stated that PjBL allows students to directly engage in research or experimental projects that require them to collect and understand scientific literature (Subagia & Sudiatmika, 2024). This process encourages students to repeatedly read scientific texts, identify relevant information, and connect theory with laboratory practice. In the long term, PjBL not only enhances conceptual understanding of chemistry but also trains students to think critically, assess information quality, and improve scientific communication skills. This approach emphasizes active and collaborative learning, enabling students to learn not only individually but also from their peers through discussions, presentations, and joint project evaluations. This significantly helps students build scientific literacy skills and reduce anxiety when facing complex English-language literature.

Strengthening Digital Literacy and Its Impact on Academic Competence

Another key approach to improving students' abilities is the reinforcement of digital literacy. In today's digital era, students' abilities are no longer limited to conventional reading or linear comprehension but require skills to access, navigate, and process scientific literature online. Digital literacy allows students to access academic sources from international databases, online journals, institutional

repositories, and the latest publications that may not be available in print. Emphasized that students with strong digital literacy are better able to navigate English-language scientific sources efficiently, search for relevant information quickly, and utilize chemical software and data analysis tools to accurately visualize research results. This enables students not only to read literature but also to analyze data, compare findings from various studies, and draw valid conclusions based on scientific evidence (Nada, 2020).

Furthermore, digital literacy assists students in academic information management. They can systematically store references using reference management software, categorize journals and articles based on topics, relevance, or research methodology, thereby facilitating the literature review process for academic assignments or research projects. This capability also supports data integration from various international journals into their research projects, allowing students to combine theory and practice comprehensively. Strong digital literacy not only supports reading ability but also enhances critical thinking, analysis, synthesis, and evaluation skills—core foundations in academic and research competence development. Additionally, digital literacy opens opportunities for students to follow the latest trends in chemistry, including utilizing preprint articles, open experimental data, and online collaborations with other researchers nationally and internationally. Students proficient in digital literacy can more easily compare research methodologies, assess source credibility, and understand different scientific contexts in English-language literature. Therefore, digital literacy not only supports content comprehension but also equips students with analytical thinking, logical argumentation, and data-driven decision-making skills in their research. Overall, strengthening digital literacy is one of the key strategies that support chemistry education students in reading and understanding English-language scientific literature effectively. This ability not only enhances individual academic competence but also encourages students to actively participate in research, write scientific papers, and present research findings in academic forums. With strong digital literacy, students can bridge the gap between complex English-language literature and their academic abilities, ultimately improving chemistry education quality, expanding scientific insight, and preparing students to compete globally in science and research.

Integration of a Holistic Approach in Developing English Literacy for Students

Overall, the combination of developing English-language chemistry textbooks, implementing Project-Based Learning (PjBL), and strengthening digital literacy forms a holistic and integrated approach to improving students' ability to read English-language scientific literature. This approach not only focuses on mechanical language improvement but simultaneously develops students' learning independence, critical thinking, scientific analysis, and broader academic competencies, including the ability to write research reports, compose scientific articles, and participate in scientific discussions. Through the development of English textbooks tailored to the chemistry curriculum context, students gain not only theoretical knowledge but also technical vocabulary, examples of scientific terminology used in research contexts, and practice in interpreting literature. Such textbooks help students recognize scientific writing patterns, understand academic

text structures, and facilitate interpreting complex information, enabling them to read literature more confidently and effectively.

The Role of Project-Based Learning and Digital Literacy in Enhancing Students' Academic Independence

In addition, the application of Project-Based Learning encourages students to actively engage in learning, both individually and collaboratively (Farida, 2021). Through PjBL, students participate in research projects that require direct comprehension of scientific literature, thereby becoming accustomed to searching, selecting, and evaluating information from various international sources. This activity promotes analytical thinking, scientific argumentation, and problem-solving skills, as students connect theory with laboratory practice and solve real-world problems encountered during projects. Active engagement in PjBL also enhances collaboration, communication, and teamwork—essential competencies in academic and international scientific research. By becoming accustomed to reading scientific literature to complete projects, students gradually improve their English literacy skills, thus significantly reducing barriers that previously hindered their understanding of academic texts (Permana & Sulastrri, 2024). Strengthening digital literacy also plays an essential role in improving students' access to English-language scientific literature. The ability to navigate scientific databases, download articles, assess source credibility, and utilize chemical software for data analysis and visualization allows students to gain a more comprehensive understanding of global research. Good digital literacy also facilitates information management, enabling students to store references systematically and integrate data from various sources into research projects or scientific reports. Thus, digital literacy not only supports reading skills but also reinforces critical thinking, analysis, and synthesis of scientific information—essential foundations for developing students' overall academic competence.

By combining learning resource development, active learning models, and digital literacy enhancement, chemistry education students are expected to significantly overcome difficulties in reading English-language literature. These strategies not only improve students' reading and comprehension abilities but also encourage them to become more independent and proactive learners. This enables students to access a broader range of international literature through online journals, research articles, and credible scientific databases, allowing them to obtain more up-to-date and relevant information in chemistry. Moreover, students with good English literacy can critically evaluate scientific information, compare research findings from various sources, and assess the quality and validity of methodologies and data—skills essential for developing academic competence at the university level.

Furthermore, improving English literacy impacts not only reading ability but also creates opportunities for students to actively participate in scientific research. Students who understand international literature well tend to be more confident in designing experiments, writing research reports, and preparing scientific articles for publication. This also promotes collaboration with other researchers, both nationally and internationally, allowing students to expand academic networks and gain diverse perspectives on current chemical issues. In addition, good English literacy enables students to participate in conferences, seminars, and international

workshops, directly enhancing scientific insight, presentation skills, and academic communication abilities.

Learning resource development strategies such as English-language textbooks adapted to students' proficiency levels, project-based learning modules, and the use of digital technology to access literature provide a holistic and contextual learning experience. The application of these approaches enables students not only to understand literary content but also to integrate such information into research projects, class discussions, and laboratory activities, creating an interactive and applicable learning process. Thus, students not only gain theoretical knowledge but also practical skills applicable in research and broader chemical science development.

Conclusion

Overall, improving English proficiency among students in the chemical education study program is essential for supporting their academic success. Strengthened English literacy enables students to access a wider range of scientific references, understand global research developments, and complete academic tasks more effectively. By enhancing their ability to comprehend and utilize English-language literature, students are better equipped to develop strong analytical skills and produce higher-quality scientific work. Ultimately, efforts to improve English proficiency are expected to help students become more competent, confident, and globally competitive chemistry educators and researchers.

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STUDENTS' EXPERIENCES AND PERCEPTIONS OF THE HABIT OF STAYING UP LATE

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Received: 4 November 2025; Accepted: 25 November 2025

Abstract

A person can be considered responsible if they consciously and intentionally do things that have a positive impact on the body. Unfortunately, in today's modern era, staying up late or sleeping late is a habit considered common among college students. This literature review aims to explore students' experiences and views on the habit of staying up late, identify its impacts on physical and mental health as well as academic activities, and formulate strategies for improving healthy lifestyle behaviors in an effort to reduce or avoid the habit of staying up late. This literature review method consists of the collection, examination, and objective analysis of data regarding the habit of staying up late in college students. The results of the literature review reveal that staying up late in college is influenced by academic demands, social activities, and ineffective time management patterns, which can disrupt sleep cycles, reduce productivity, increase the risk of emotional disorders, and worsen concentration. The findings indicate that the habit of staying up late has a significant impact on students' well-being, both physically and mentally.

Keywords: experience, health, perception, staying up late, students

Introduction

A person can be said to be responsible if they consciously and deliberately engage in actions that have a positive impact on their body. One form of responsibility toward oneself is maintaining good health. Health is the stable condition of a person's body and mind. Maintaining physical health can begin with managing sleep patterns, exercising regularly, and eating nutritious, healthy foods. However, nowadays, responsibility for maintaining one's health is often neglected. One habit that is common among young people, especially university students, is staying up late or sleeping very late at night. Staying up late has become a trend that is difficult to avoid. High academic demands, poor time management, addiction to online games, and social pressures are often the main reasons why many students stay up late. Without realizing it, this habit, if done continuously over a long period, can have adverse effects on health, such as increasing the risk of heart disease, stroke, and diabetes, as well as causing depression, lowering the immune system, and reducing cognitive ability. Long-term inadequate sleep patterns are thought to disrupt hormonal balance and the body's recovery process. In women, this condition can make the body more vulnerable and potentially increase the risk of breast cancer



(Naqeeb et al., 2024). Therefore, staying up late has a significant impact on health. To prevent the various negative effects of staying up late, getting sufficient sleep provides important benefits for maintaining the balance of bodily functions (Zahrani, 2022).

To avoid these negative effects, getting enough sleep has significant benefits for maintaining health and the body's balance. Sleep is a state in which the body is in a resting phase, characterized by a decrease in consciousness and responsiveness to stimuli. Sleep affects almost every type of tissue, organ, and system in the body. It plays a crucial role in regulating brain function, including how nerve cells (neurons) communicate with each other so that the brain can process information effectively. Everyone needs sufficient sleep. For adults, the recommended amount of sleep per day is seven to eight hours. During sleep, the body quickly produces immune system components, restores energy, and repairs damaged cells. This literature aims to explore students' experiences and perspectives on the habit of staying up late, as well as to identify its impact on physical health, mental well-being, and academic performance. Thus, this study is expected to raise students' awareness of the importance of maintaining healthy sleep patterns.

Method

This study used a literature review method to objectively collect, review, and analyze data regarding students' perceptions and sleep habits. A literature review is a method conducted by searching, reviewing, analyzing, and drawing conclusions from various sources. This method provides an overview of students' perceptions and sleep habits based on previous research and existing theories. Data collection was conducted by reviewing academic sources such as scientific articles, journals, and reports using Google and Google Scholar, using the keywords staying up late, students, experience, perception, and health. The criteria for inclusion were articles published within the last 15 years, from 2010 to 2025, and journal titles and content that align with the research objectives. The collected data were categorized based on factors contributing to students' sleep habits, including academic, psychological, technological, and environmental factors. The information obtained from these various scientific sources was then used as a basis for formulating strategies to promote healthy lifestyles, specifically efforts to reduce or avoid staying up late.

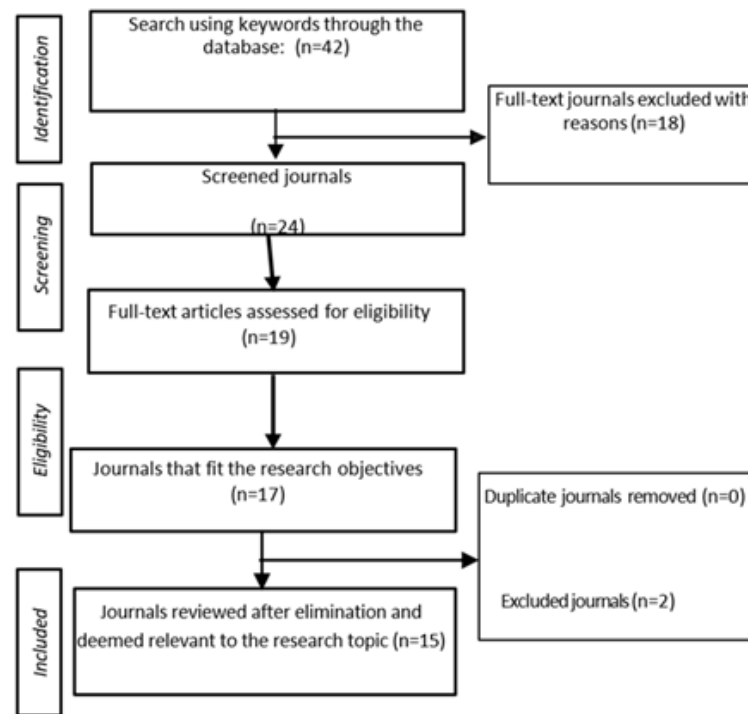


Figure 1. Data Collection

Findings and Discussion

This section presents the findings from the literature review related to the habit of staying up late among university students. Based on the review of various sources, it was found that most students tend to stay up late due to various internal and external factors. Students' perceptions of their ability to stay up late are the initial factors influencing the formation of this habit.

Students' Perceptions of the Habit of Staying Up Late

Based on the research findings, many university students perceive staying up late as a condition in which someone delays their nighttime rest, goes to bed past midnight, or even remains awake until morning (Madelu et al., 2025). Many students consider going to bed late as something normal because they are already accustomed to academic assignments, organizational activities, and social engagements. According to Zahrani, some students still lack awareness of the risks and consequences associated with staying up late (Zahrani, 2020).

Factors Affecting the Habit of Staying Up Late

The literature review shows that one of the main factors influencing students' habit of staying up late is excessive use of mobile phones or gadgets, which can cause them to lose track of time. A study conducted among nursing students found that gadget use is negatively correlated with sleep quality (Bees & Haro, 2022). In addition, Lubis et al. (2021) reported that medical students who used smartphones for more than two hours at night had poorer sleep quality compared to those who used them for a shorter duration. Smartphone addiction has also been shown to be associated with impaired sleep quality among medical students at Nusa Cendana University (Firmansyah et al., 2019). Additional factors, such as academic stress,

further worsen this relationship. A study by Fazril et al. (2024) found that smartphone addiction and academic stress together contribute to decreased sleep quality among students.

The Impact of the Habit of Staying Up Late on Student Activities

Sleep quality and duration have a significant relationship with students' academic performance. The study by Okano et al. (2019), which examined first-year university students, found that their average sleep duration was only about 6 hours and 37 minutes per night—far below the recommended 8–10 hours of sleep for adolescents and young adults. In addition, research by Lund et al. (2010) reported that first-year students are more prone to experiencing sleep disturbances because they are in a transitional phase that requires adaptation to increased academic demands and a new social environment. Findings from other studies also indicate that students with poor sleep quality in the early semester tend to experience decreased academic productivity, heightened stress levels, and reduced concentration ability (Gilbert & Weaver, 2010). The study further revealed that shorter sleep duration is associated with lower GPA outcomes, whereas students with sufficient sleep duration tend to achieve higher GPAs at the end of the semester, as also supported by Baert et al. (2015).

Discussion

Based on the findings that describe students' perceptions of staying up late, this habit has become normalized among many university students, even though it actually has harmful effects that are often overlooked. It can be clearly observed that students' understanding of the risks associated with staying up late is still very limited, making it important to increase their awareness of its negative consequences. Without awareness that comes from within themselves, students tend to continue engaging in this habit, which has the potential to negatively impact their health (Madelu et al., 2025).

In addition, differences in students' ability to cope with staying up late also influence this behavior. Not all students feel comfortable staying awake until late at night. Some students are unable to maintain focus and feel extremely fatigued when attempting to stay up late, leading them to choose to sleep earlier. Conversely, other students feel capable and do not experience significant difficulty when staying up late, which makes them more likely to do so. These differing perceptions often arise from habits such as completing assignments late at night or participating in demanding campus activities. Going to bed late is frequently viewed as an act of responsibility to complete academic tasks or as the only available time to relax after a busy day. This mindset reinforces the continuation of staying up late, even when students are aware of its negative effects (Zahrani, 2020).

Excessive smartphone use, academic stress, and poor time management are the main factors influencing students' habit of staying up late. This discussion illustrates how these variables are interconnected and contribute to the deterioration of students' sleep patterns. There is a direct correlation between nighttime smartphone use and poorer sleep quality. This aligns with the findings of Bees & Haro (2022), who reported a negative relationship between electronic device usage and sleep quality. Lubis et al. (2021) further support this by showing that medical students who use smartphones for more than two hours each night experience lower sleep quality.

According to Firmansyah et al. (2019), smartphone addiction among students at Universitas Nusa Cendana negatively impacts their ability to sleep well and the duration of their sleep. Additionally, social media addiction also contributes to delayed bedtime, as constantly updated content, curiosity-triggering notifications, and habitual scrolling unintentionally make time pass quickly.

Academic stress from tasks such as coursework, lab reports, thesis writing, and exam preparation can also influence students to stay awake late at night. Students with poor time management are more likely to procrastinate, which forces them to stay up late to complete their responsibilities (Wiratama & Bustamam, 2022). Furthermore, the social environment around students' residences plays a role. For example, students living in dormitories or boarding houses often engage in group activities such as playing, watching shows, or chatting late at night. Noisy or uncondusive environments can make it difficult for students to get sufficient rest. Another contributing factor is students' physical condition, such as experiencing difficulty sleeping or having irregular sleep rhythms. Daytime napping for extended periods can also result in staying awake longer at night (Adharina et al., 2015). This discussion demonstrates that these variables are interconnected and can exacerbate poor sleep patterns. When academic demands, social media use, and environmental influences occur simultaneously, the likelihood of staying up late increases.

Findings from various journals indicate that the habit of staying up late and sleep deprivation is not merely a poor lifestyle choice but a significant factor affecting students' ability to engage in academic activities. The average sleep duration of first-year students, which is only around 6 hours and 37 minutes (Okano et al., 2019), reflects a discrepancy between the body's biological needs and the actual sleep patterns formed during college life. This sleep insufficiency should be understood in the context of the transitional phase of new students' lives, characterized by increased academic workload, social adaptation demands, and suboptimal time management (Lund et al., 2010). Such conditions make students more susceptible to sleep disturbances and cognitive fatigue.

The consistent association between poor sleep quality and decreased academic productivity, increased stress, and reduced concentration ability (Gilbert & Weaver, 2010) reinforces the understanding that sleep is an essential part of cognitive recovery. When students sleep for shorter durations, the brain does not have sufficient time for memory consolidation and neural system recovery, affecting daily learning abilities. This explains why shorter sleep duration is associated with lower GPA, while students with optimal sleep quality and duration tend to achieve better academic performance (Baert et al., 2015).

Sleep quality plays a very important role in students' physical health, mental well-being, and academic performance. Adequate sleep duration has a positive effect on academic achievement (GPA). Health guidelines state that adolescents should get 8 to 10 hours of sleep per night. However, a study focusing on the sleep duration of first-year university students found that their average sleep duration at night was around 6 hours and 37 minutes. First-year students are generally in a transitional phase and face significant adaptation pressures, such as increasing academic workloads, causing their sleep patterns to be more disrupted than those of senior students, who are usually better at managing their time and sleep routines. Sleep disturbances among first-year students can negatively affect academic performance and overall health. Other studies have added that the quality, duration,

and consistency of sleep are closely related to students' ability to maintain concentration in learning and their psychological well-being. Students with poor sleep quality in their first semester tend to experience a decline in academic productivity and higher levels of stress. Shorter sleep duration among first-year students may result in lower GPA scores at the end of the semester, while adequate sleep duration is associated with higher GPA outcomes.

Table 1. The relationship between sleep duration and GPA

TST	n	Spring term GPA	GPA change
<6 h	107	3.25	-0.13
6 to 7 h	262	3.48	0.02
7+ h	188	3.51	0.01

(Creswell *et al.*, 2023)

Notes: GPA change is the spring term GPA minus the student's baseline GPA

In the study by Creswell *et al.* (2023), the sample consisted of first-year students from three different universities, totaling more than 600 participants. Sleep duration data were collected using actigraphy, a sleep-tracking device worn on the wrist, over approximately one month at the beginning of the semester. The average sleep duration of students during this period was around 6 hours and 37 minutes per night, well below the recommended sleep duration for adolescents and young adults, which is 8–10 hours per night. Based on the table, it can be observed that nighttime sleep duration is related to the academic performance of first-year university students. Students who sleep less than six hours per night have an average GPA of 3.25, showing a decrease of 0.13 compared to the previous semester. However, students who sleep between six and seven hours or more than seven hours per night have higher average GPAs of 3.48 and 3.51, respectively. This indicates that sufficient sleep duration has a positive impact on improving students' academic achievement and performance (Creswell *et al.*, 2023).

Students who frequently stay up late report experiencing various negative effects the following day. They feel less energetic, find it difficult to concentrate, struggle to wake up in the morning, become easily drowsy during lectures, and often experience headaches. If these conditions persist, they not only affect physical well-being but also have an impact on students' academic performance and emotional state. When the body feels weak and lacks energy, daily activities become less optimal. Students' focus and attention tend to decrease when their bodies are fatigued. In comparison, students who get enough sleep are generally more capable of maintaining focus and concentration during lectures.

Sleep quality and learning concentration are two interrelated aspects. Good quality sleep can improve students' focus and concentration. Poor sleep quality often leads to decreased concentration and memory ability, which can negatively affect critical thinking skills. When students have difficulty concentrating due to staying up late, they tend to feel sleepy and experience headaches, which can lower their academic performance. Students may also experience stress due to insufficient rest, which can affect their overall well-being. In addition to headaches, staying up late can weaken the immune system, making individuals more susceptible to illness, and it can also lead to mood changes. Mood refers to a person's internal emotional state or feelings, which can only be fully understood by the individual themselves.

Mood changes are one of the psychological effects of the habit of staying up late. A lack of adequate rest can disrupt hormonal balance in the body, especially hormones such as serotonin and cortisol, which play key roles in regulating emotions. When someone frequently stays up late, levels of the stress hormone cortisol increase, while the production of serotonin, the hormone responsible for maintaining feelings of happiness, decreases. This imbalance causes individuals to become more prone to feelings of anxiety, sadness, anger, or loss of motivation. Prolonged sleep deprivation can even lead to psychological disorders such as depression and anxiety (Nurlela et al., 2023).

According to the literature, negative moods tend to appear in the morning when students do not get enough rest. These negative moods include feelings of anger, irritability, sadness, fatigue, headaches, and weakened immunity. However, each student experiences mood changes differently, so many are still able to manage and control their emotional states despite insufficient rest.

Mood in a State of Fatigue or Laziness

Students who stay up late report that their mood can become an obstacle when carrying out important activities or tasks. Mood fluctuations often lead to feelings of laziness, which in turn cause delays in completing activities. Fatigue resulting from frequent late nights can be observed through several physical and behavioral signs. Individuals who have the habit of staying up late usually show symptoms such as difficulty falling asleep early, decreased appetite, oversleeping in the morning, increased vulnerability to illness, and the appearance of dark circles under the eyes.

Mood in a State of Anger or Irritability

Mood refers to a person's internal emotional state, which can only be fully understood by themselves. After staying up late, a person's mood can change drastically, with the most common impact being increased sensitivity, such as becoming easily irritated or angry without a clear reason. This negative mood is reflected in everyday behaviors, including restlessness, lack of motivation, decreased self-confidence, and even depression. Staying up late not only affects emotions but also has serious consequences for physical health.

Sleep deprivation can make the body easily fatigued, disrupt deep sleep, and weaken immunity. Several studies on adults have shown that insufficient sleep may be linked to diseases such as diabetes, obesity, or heart problems, although these findings may not directly apply to university students. Among students, the most common effects are fatigue, difficulty concentrating, and increased susceptibility to illness. Lack of sleep can also affect the body's energy regulation, potentially leading to weight gain. If this pattern of insufficient sleep continues, the body does not have enough time to recover, which may trigger health problems in the future. The impact on mental health includes mood instability, stress, anxiety, and depression. According to the American Psychological Association, insufficient sleep can impair a person's ability to cope with stress and worsen mental conditions, such as reduced concentration, memory problems, and poor decision-making due to inadequate rest (Cappuccio et al., 2010).

How to Eliminate the Habit of Staying Up Late

Based on the findings that have been summarized, there are several ways to reduce the habit of staying up late. The first step is to get used to sleeping earlier and avoid using mobile phones before bedtime. The use of mobile phones should be limited by turning them off or placing them away from the bed to avoid the temptation of checking social media or responding to notifications. If there are assignments that need to be completed, students can apply good time management by scheduling their work in the afternoon or evening so that they do not have to stay up late to finish it. In addition, making a personal commitment to determine bedtime and wake-up time can help establish a regular sleep rhythm (Harahap & Siregar, 2023).

Efforts to overcome the habit of staying up late not only depend on personal intentions but also require support from academic and social environments. This support is important because the intention to change often arises from understanding gained through education and social interaction. The campus environment can play an active role by organizing seminars or educational programs that discuss the importance of sufficient and quality sleep. Topics that can be addressed in such activities include effective time management, relaxation techniques to reduce stress, and ways to build healthy sleep routines (Arifin et al., 2024).

Furthermore, a psychologically based strategy is needed to encourage behavioral change among students regarding sleep patterns. Dautovich et al. (2021), in the *International Journal of Environmental Research and Public Health*, developed a classroom-based learning strategy using the Self-Determination Theory approach. This approach helps students improve their sleep patterns by strengthening internal motivation and positive environmental support. In the study, students participated in a short 20-minute classroom intervention designed to meet three main psychological needs: competence, autonomy, and social connectedness. In the initial stage, students were asked to reflect on their sleep habits and write down positive things they had already done well. Next, they developed three SMART goals (*Specific, Measurable, Achievable, Realistic, and Time-bound*) related to improving sleep quality, such as maintaining consistent sleep schedules, fulfilling seven to nine hours of sleep per night, and reducing electronic device usage before bedtime. After setting these goals, students selected one main goal that was most relevant and discussed it with classmates to find solutions to possible obstacles. Through this activity, students were encouraged to take greater responsibility for their sleep patterns while also receiving social support from their learning environment.

The research findings indicate that most students focus on improving sleep hygiene, tech hygiene, consistency in sleep schedules, and stimulus control. Sleep hygiene involves habits such as avoiding caffeine or nicotine in the evening, reducing daytime naps, and creating a calm and comfortable bedroom environment. At the same time, tech hygiene emphasizes the importance of limiting the use of mobile phones or digital devices before bedtime, for example, by turning off laptops and televisions or keeping gadgets away from the bed. Consistent sleep schedules and stimulus control encourage students to go to bed and wake up at the same time every day and to use the bed only for resting. The implementation of these simple

steps has been proven to help students reduce late-night sleeping habits and improve overall sleep quality.

Table 2. Analysis results from a survey or questionnaire on sleep habits

Theme	Representative Response	% of Sample
Rhythmicity/Timing of Wake and Sleep	“Something that I already do well regarding sleep habits is that I sleep and wake up around the same time every day.”	24.21%
Prioritizing Sleep Duration	“I get the suggested amount of sleep for my age every night.”	22.14%
General Sleep Timing	“I try to go to sleep no later than 1 am, that’s my stopping point.”	11.43%
Tech Hygiene	“I don’t look at my phone before going to sleep, as the blue light emitted from a cell phone can make it hard to go to sleep and keep me up longer.”	10.71%
Sleep Hygiene	“I don’t drink caffeine towards the end of the day.”	7.86%
Bedtime Routine	“I have a nightly routine that helps prepare my body and mind for rest.”	7.14%
Other (monitoring, substances)	“Take melatonin to fall asleep faster/easier.”	7.14%
Daytime Activities	“I always try to do my homework early so that I am not up late at night working on it.”	3.57%
Stimulus Control	“Something I already do well regarding my sleep habits is sleep when sleepy. When I get really tired, I just head to bed and slump.”	2.86%
Creating an Environment Conducive to Sleep	“I sleep with two fans on and have many pillows and blankets in my comfy bed.”	2.86%

In addition to the quantitative results, the qualitative analysis in this study also illustrates that students already had several positive habits related to sleep patterns before participating in the intervention. Based on the table above, most respondents reported maintaining regular sleep and wake times each day (24.21%) and making efforts to achieve sleep durations appropriate for their age (22.14%). Some students also reported going to bed before 1:00 a.m. (11.43%) and limiting phone usage before bedtime to avoid blue light exposure, which can disrupt sleep (10.71%). Additionally, some practiced healthy habits such as avoiding caffeine in the evening, maintaining a consistent bedtime routine, and creating a comfortable bedroom environment to facilitate rest (7.86%). These results indicate that a self-motivation-based approach is effective in helping students abandon the habit of staying up late and replace it with healthier sleep patterns (Dautovich et al., 2021). Overall, the findings show that staying up late is a common behavior among university students, but it has negative consequences for physical, mental, and academic health. Therefore, students need to develop awareness of maintaining healthy sleep patterns as a form of responsibility toward themselves and their overall well-being.

Conclusion

Based on the literature review conducted, it can be concluded that the habit of staying up late among university students is largely caused by excessive phone use, academic assignments, and poor time management. These factors lead students to sleep later at night, reducing their overall sleep quality. Many students consider staying up late to be normal, even though they are not fully aware of the negative impacts of this habit. Findings from the literature indicate that lack of sleep has a direct impact on students' physical condition and learning ability. Several studies show that many students sleep less than the normal requirement, making them more prone to fatigue and sleep disturbances, especially during the early years of college when academic demands increase. In addition, poor sleep quality can cause students to experience stress, difficulty concentrating, and potentially lower academic performance compared to those who get sufficient sleep. Sleep deprivation affects not only the body but also the mood, often resulting in irritability, fatigue, and a lack of motivation.

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CULTURALLY RESPONSIVE EARLY CHILDHOOD EDUCATION: TEACHERS' PERSPECTIVES AND PRACTICES ON LOCAL CULTURE IN INDONESIA

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Received: 6 October 2025; Accepted: 25 November 2025

Abstract

In response to cultural homogenization driven by globalization, integrating local culture into early childhood education (ECE) supports culturally responsive pedagogy. This study explores how ECE teachers in Indonesia perceive and apply local culture in curriculum and lesson planning. Using a cross-sectional survey of 74 teachers in Lebak Regency, Banten, the study analyzed cultural awareness, planning behavior, and teaching strategies. Results show that teachers value local traditions and incorporate food, clothing, games, housing, and folklore into classroom activities using project-based learning, field trips, and discussions. These are commonly integrated into thematic units like “My Environment” and “My Country.” However, only 30.41% of teachers formally document cultural elements in lesson plans, indicating a gap between practice and written curriculum. This gap may hinder the formal preservation of intangible heritage. The study highlights the need for institutional support and professional development to strengthen the alignment between teaching practices and curriculum documentation.

Keywords: culturally responsive pedagogy, curriculum integration, early childhood education, globalization, local culture

Introduction

Early childhood education (ECE) represents a foundational stage in children's cognitive, emotional, social, and cultural development. During this critical period, teachers play a pivotal role not only in facilitating learning but also in shaping children's values, attitudes, and sense of identity. A key avenue through which this role is realized is the integration of local culture into the curriculum. Embedding cultural elements in early education fosters children's understanding of heritage, strengthens cultural identity, and cultivates respect for diversity. This approach aligns with the principles of culturally responsive pedagogy, which emphasizes the importance of drawing on students' cultural backgrounds to enhance learning (Gay, 2000; Ladson-Billings, 1995).

In this context, culture is not merely a collection of artifacts or traditions but a dynamic system of meanings that shapes worldviews and behavior. Groh (2019) defines culture as socially transmitted patterns of behavior, values, and symbols, while Geertz (1973) describes it as historically transmitted meanings embodied in symbols. For young children, cultural learning is most effective when it is grounded



in their immediate environment and everyday experiences, making local culture especially relevant.

In Indonesia, the integration of local culture into education is both encouraged and mandated by national policy. Article 36 of Law No. 20/2003 on the National Education System requires that curriculum development take into account the cultural diversity of society. This principle reflects the educational philosophy of Ki Hajar Dewantara, who advocated for instruction that reinforces national identity and cultural awareness from an early age.

Despite national mandates, the implementation of local culture in early childhood education (ECE) remains challenging. Globalization, technological advancement, and urbanization have contributed to the gradual erosion of traditional cultural practices, rendering them less visible in daily life. As a result, young children risk becoming increasingly disconnected from their cultural roots unless educators take deliberate action to bridge this gap. ECE teachers are thus positioned as cultural agents, responsible for designing learning experiences that meaningfully connect children to their heritage.

While previous studies have examined culturally responsive teaching in ECE (Alaca & Pyle, 2018; Shih, 2022) there remains limited empirical evidence on how teachers perceive, plan, and integrate local cultural content—particularly in rural, culturally rich regions such as Lebak Regency in Banten Province. Much of the existing literature focuses on urban or Western contexts, creating a gap in understanding culturally responsive practices in non-Western and underrepresented settings.

This study seeks to address that gap by investigating how kindergarten teachers in Lebak understand and implement local cultural elements in their curriculum. With its strong cultural heritage, Lebak serves as an ideal context to explore how early education can support cultural preservation. By examining teachers' perceptions, curriculum design, and pedagogical strategies, this research offers new insights into the enactment of culturally responsive pedagogy in rural Indonesia and informs curriculum development, teacher preparation, and policy for cultural sustainability.

Theoretical Framework

This study is informed by two complementary theoretical frameworks: Vygotsky's sociocultural theory and Dewey's experiential learning model. Together, these perspectives provide a robust foundation for understanding how culturally embedded practices can serve as meaningful contexts for fostering critical thinking in early childhood education—particularly in non-Western contexts such as Indonesia, which remain underrepresented in existing research.

C. P. D. (1978) emphasized that learning and development are inherently social and cultural processes. Cognitive growth begins at the interpersonal level through interaction with others before being internalized at the intrapersonal level. Central to his theory is the concept of the Zone of Proximal Development (ZPD), defined as the distance between what a child can accomplish independently and what they can achieve with appropriate guidance. Within the ZPD, adult mediation and peer collaboration are essential, as communication and shared activities serve as tools for internalizing culturally meaningful knowledge. Through these social

exchanges, children are gradually able to participate in and master culturally valued practices, thereby linking cognitive development with cultural transmission.

Guided participation, an extension of Vygotsky's theory, highlights the active involvement of children alongside more knowledgeable members of their community—such as parents, teachers, siblings, and neighbors—in everyday cultural practices. Through these collaborative interactions, children not only develop practical skills but also internalize culturally valued modes of thinking. Contemporary scholars (Edwards et al., 2019) have extended Vygotsky's framework by emphasizing the role of culturally responsive pedagogy in early childhood education, stressing the importance of embedding learning within meaningful local contexts.

In parallel, Dewey (2004) experiential learning theory conceptualizes education as a continuous process of reconstructing experience through interaction between the child and their environment. Dewey argued that learning is most effective when rooted in real-life experiences that are socially and culturally relevant to the learner. He positioned educators as facilitators who structure and guide these experiences to foster reflective thinking and social competence. According to Dewey, meaningful learning emerges through active participation, inquiry, and reflection within the child's lived context. Together, these theoretical perspectives frame this study's investigation into how adult-child interactions—mediated by local cultural narratives and community practices—can support the development of critical thinking as a higher-order cognitive skill. By anchoring early childhood learning in familiar cultural experiences, this approach provides a nuanced and contextually grounded pathway for advancing children's cognitive and social development.

Method

Research Design

This study employed a quantitative approach using a cross-sectional survey design. The primary objective was to investigate kindergarten teachers' perspectives and practices concerning the integration of local cultural elements into early childhood education. The cross-sectional design allowed data to be collected at a single point in time, offering a comprehensive snapshot of current practices across several sub-districts in Indonesia.

Participants

The study involved 74 kindergarten teachers from seven sub-districts in Lebak Regency, Banten Province, Indonesia: Gunung Kencana, Cijaku, Warung Gunung, Muncang, Malimping, Rangkasbitung, and Cibadak. These sub-districts were selected using random sampling, with accessibility as a key consideration. Participation was voluntary, and participants were selected based on their availability during the data collection period. All participants had prior experience teaching young children and were actively involved in implementing the early childhood curriculum.

Data Collection Procedure

Data were collected over a two-week period using an online questionnaire distributed via Google Forms. The instrument comprised both closed-ended

(Likert-scale) items and open-ended questions designed to explore teachers' beliefs, planning behaviors, and pedagogical strategies related to local culture. The questionnaire was informed by the literature on culturally responsive pedagogy and reviewed by experts in early childhood education to ensure content validity and alignment with the study's objectives. Collaboration with local education coordinators supported the distribution and follow-up process. Prior to completing the survey, participants were provided with detailed information about the study and gave informed consent. Participation was voluntary, and all responses were kept confidential.

Data Analysis

Descriptive statistics, including frequency distributions and percentage calculations, were used to analyze the quantitative data. Open-ended responses were examined using thematic analysis to identify recurring themes and patterns. Although no formal validity or reliability testing was conducted, expert reviews guided the questionnaire design to enhance content relevance and internal consistency.

Findings and Discussion

Knowledge of local culture

Children's development is inherently shaped by the environments in which they live, with the cultural context embedded in daily life playing a significant role. The term culture originates from the Sanskrit word *Buddayah*, the plural of *Budi*, meaning "reason." Culture encompasses the traditions, practices, and social norms manifested in the institutions and daily interactions of a community (Ødegaard & Hedegaard, 2020). It includes the collective ways of life—such as religion, food, clothing, language, rituals, and music—that characterize a group. Furthermore, culture is understood as a system of shared ideas, values, beliefs, knowledge, and customs that are passed down through generations, often extending beyond local contexts to the international level (Groh, 2019).

A survey conducted among kindergarten teachers in Lebak Regency revealed that 80% of the 74 participants demonstrated an accurate understanding of local culture. These respondents described local culture as the unique heritage of a particular region, distinct from that of other areas, and transmitted intergenerationally. In contrast, 8% of teachers misinterpreted local culture merely as the customs surrounding them, while the remaining 12% provided incorrect or unclear responses, such as identifying local culture as Indonesia's original culture, preserved culture in nearby environments, or a form of culture that is natural and unaffected by external influences.

Regarding the importance of kindergarten teachers' knowledge of local culture, 63% of respondents stated that such knowledge enables them to effectively provide culturally relevant learning experiences for children. Specifically, they emphasized that: 1) As kindergarten teachers, they are responsible for transferring cultural knowledge to children, and the broader the teacher's understanding, the richer the material the children can receive; 2) This knowledge allows teachers to deliver appropriate cultural education within the learning process; 3) Teachers can educate children about local traditions and help preserve them; and 4) Introducing local culture enables children to recognize the cultural richness and diversity in their

region, fostering a sense of care and respect for cultural heritage. Furthermore, local cultural wisdom is considered essential in shaping children's moral character and instilling noble values. An additional 30% of respondents noted that understanding local culture enhances: 1) Teachers' insight and knowledge of their own cultural context; 2) Appreciation and acceptance of cultural differences across regions; 3) Adaptability to the community environment; and 4) Respect for regional diversity, which they also identified as important for self-improvement. The remaining 7% of responses were less relevant or did not directly address the question.

Integrating local culture into early childhood education not only supports children's learning within their sociocultural context but also prepares them to engage with broader societal challenges both now and in the future (Widiastuti, 2012). Culture plays a central role in shaping how children learn, interact, form relationships, and share information. In this context, culture refers to the shared understandings, behaviors, traditions, and values that define a particular group. It provides a lens through which individuals interpret their environment and connect with others. Thus, culture influences daily life, behavior, and the ways individuals participate in their communities. In Lebak Regency, various local cultures coexist, and teachers demonstrate awareness of this cultural richness, as illustrated in the following figure 1.

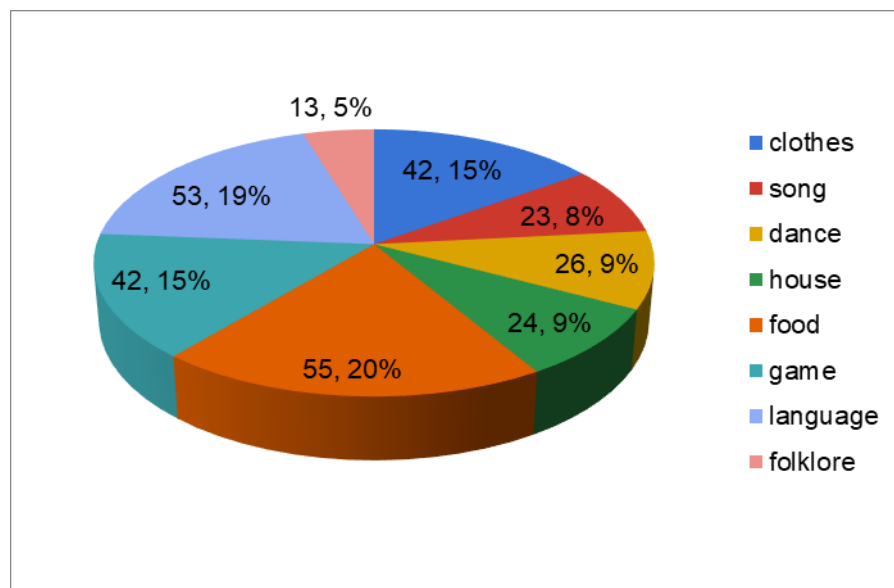


Figure 1: Types of Lebak Culture

Based on the data presented in Figure 1, it is evident that teachers are able to identify several cultural elements that are still preserved in the Lebak area, Banten. The majority of respondents demonstrated awareness of regional foods (20%), local language (19%), traditional games (15%), and traditional clothing (15%). A smaller proportion mentioned folklore, regional songs, traditional dances, and traditional houses. The specific names of the cultural elements mentioned by the respondents are detailed in the following Table 1.

Table 1: Known Cultures and Their Types/Names

No.	Known Culture	Type/ name of culture
1	Traditional food	Rabeg, Sate Bandeng, Karedok, Sayur Asem, Angeun Lada, Ayam Bakakak, Opak Singkong, Jojong, Pasung, Emping, Keceprek, Kue Cincing, Lotek, Gemblong, Ketimus, Rengginang, Gipang, Serabi, Apem
2	Traditional games	Engkle, Kolecer, Jajangkungan, Gatrik, Oray-Orayan, Boy-Boyan, Cingciripit, Sempring
3	Traditional clothing	Batik Lebak, Batik Baduy, Baju Kampret, Jamang Nyangsang/ Kutung, Koncer/ Lomar/ Telekung, Pangsi
4	Folk songs	Rangkasbitung, Bubuy Bulan, Ngarengkong, Dayung Sampan, Tong Sarakah, Cing Cang Keling, Manuk Dadali, Basisir Carita, Pileuleuyan, Tokecang, Cingciripit, Jereh Bu Guru, Laut Kidul, Surantang Surinting
5	Traditional dance	Jaipong, Grebeg Terbang Gede, Manuk Dadali, Rampak Bedug, Tepak Tilu, Bendrong Lesung
6	Traditional house	Leuit, Julang Ngapak, Sulah Nyanda, Jalopong
7	folklore	Rangkasbitung history, Warunggunung history, Pandeglang, Baduy Tribe story Si Kancil Mencuri Timun, Tanjung Lesung/ Raden Budog, Saija Adindan, history of Old Banten
8	Local language	Sunda

This cultural knowledge needs to be introduced to children as future generations and as key agents in preserving existing local traditions.

Inclusion of local cultural material in the curriculum and learning plans

Local culture should be introduced to children through the learning process; therefore, it needs to be integrated into the curriculum. Based on the survey results, 33% of respondents stated that incorporating local culture into the curriculum is very necessary, while 47% considered it necessary. The remaining 20% were less certain or did not express a clear opinion.

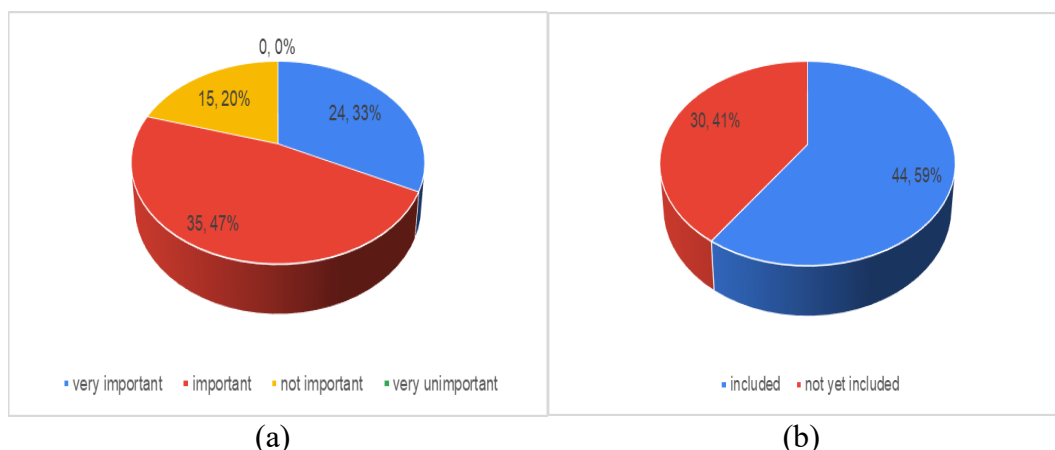


Figure 2: The Importance of Incorporating Local Culture into the Curriculum (a); Local Culture Incorporation into the Curriculum (b)

However, despite the recognition of its importance, only 59% of those who viewed it as necessary or very necessary had actually included local culture in their curriculum, while 41% had not (see image above right). The reasons for these responses are illustrated in the figure 3 below.

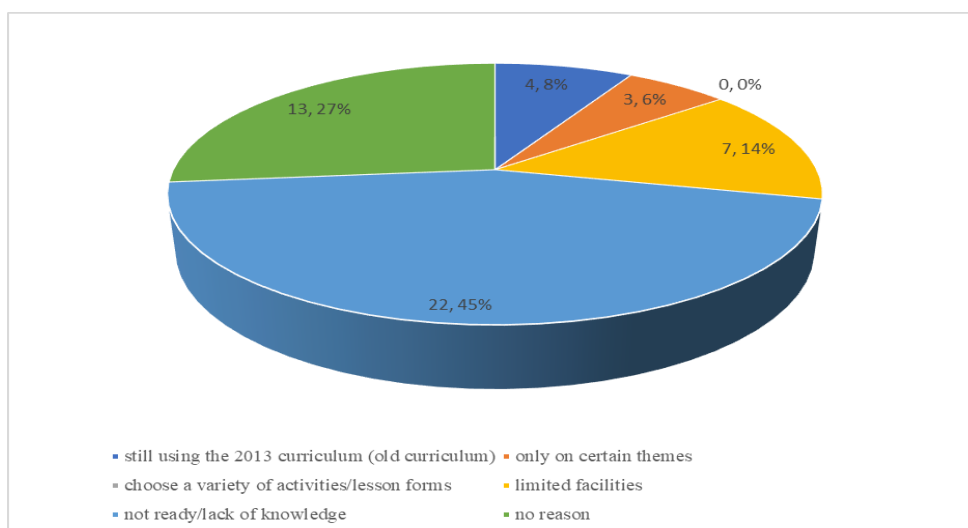


Figure 3: Reasons for Not Including Local Culture in the Curriculum

The primary obstacle preventing teachers from integrating local culture into the curriculum is a lack of knowledge, cited by 45% of respondents. An additional 14% identified limited facilities as a constraint, while 27% did not provide a specific reason. The integration of local culture into the curriculum is a vital initiative aimed at preserving cultural heritage, emphasizing the importance of actions that support the foundational elements of societal life. Preschool curricula should be designed to encourage children to engage in play and exploration within their everyday environments and communities, thereby laying the foundation for deeper exploration and reflection in later stages of education (Ødegaard & Hedegaard, 2020)

The importance of incorporating local culture into early childhood education is underscored by Taiwan's curriculum model, which seeks to transmit cultural

concepts, values, beliefs, knowledge, and customs across generations (Shih, 2022). In Indonesia, the Ministry of Education, Culture, Research, and Technology highlights culture as a core principle in learning, which must be thoughtfully considered and implemented. National guidelines emphasize that learning should be relevant, contextually grounded, and culturally responsive, involving parents and the community as educational partners. Educators are encouraged to design learning experiences that are needs-based and connected to real-world contexts, the environment, and local culture in order to foster students' interest and engagement (Anggraena et al., 2022). Therefore, the notion that educators refrain from incorporating local culture due to the continued use of the 2013 Curriculum (Kurikulum 2013 or Kurtilas) appears to be inaccurate. When cultural content is included in the curriculum, it should be reflected in instructional planning and subsequently implemented in teaching practices. Related to this, survey data show that 32% of respondents considered it very important and 54% considered it important to integrate local culture into lesson planning, while 14% viewed it as unimportant.

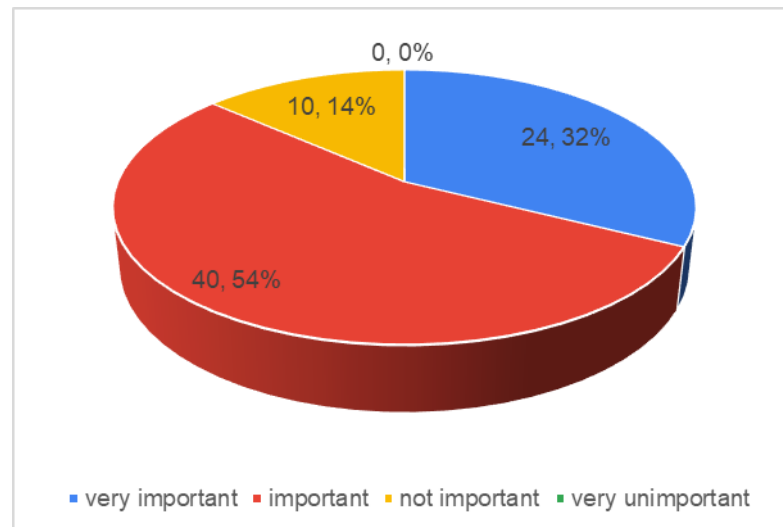


Figure 4: The Importance of Including Local Culture in Learning Planning

Nevertheless, although the importance of incorporating local culture into lesson planning is acknowledged by the majority of respondents, its practical implementation remains inconsistent. Only 35% of respondents reported that they consistently integrated local cultural content into their lesson plans. In contrast, 42% stated that they did so occasionally, and 23% acknowledged that they had not included it at all. The reasons for the infrequent or absent inclusion are attributed to several challenges, as illustrated in the figure below.

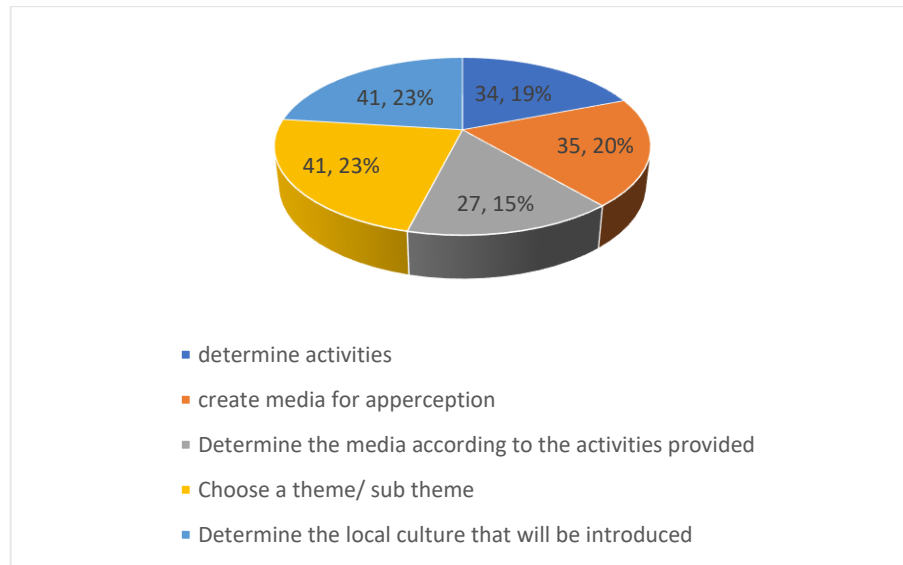


Figure 5: Difficulties in Preparing Plans Related to Local Culture

The figure illustrates that educators encounter challenges in developing lesson plans, particularly in selecting appropriate themes (23%) and determining which aspects of local culture to introduce to young children. In the context of early childhood education in Indonesia, the 2013 curriculum continues to adopt a thematic learning approach. Thematic learning is designed to integrate knowledge, skills, values, attitudes, and creative thinking through a unifying theme. The curriculum comprises 11 themes, distributed across two semesters. The first semester covers the themes of Myself, My Family, the Environment, and Animals, while the second semester includes the themes of Plants, Vehicles, the Universe, and My Country. The themes most commonly used by respondents to introduce elements of local culture are presented in the following figure.

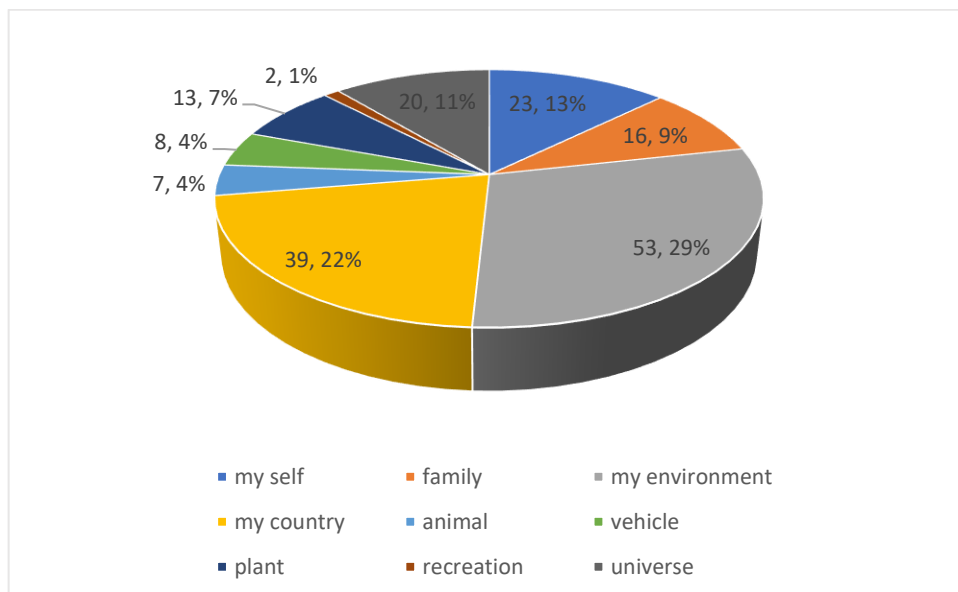


Figure 6: Themes for Introducing Local Culture

Based on the illustration, it is evident that local culture is most frequently introduced through the theme *My Environment* (34%), followed by *My Country* (18%). The environment serves as a medium in which living beings reside and interact, possessing unique characteristics and functions that are reciprocally related to the existence of those inhabiting it, particularly humans, who play a more complex and active role (Rusdina, 2015). Children must be introduced to their environment to foster an understanding of their surroundings, including the physical setting, community members, and prevalent cultural practices. The environment also serves as a learning resource for children, offering diverse facilities and information that support the development of their full potential. According to the Indonesian Minister of National Education Regulation No. 58 of 2009 on Early Childhood Education Standards, early childhood infrastructure must: (1) be safe, comfortable, well-lit, and meet children's health standards; (2) align with developmental stages; and (3) utilize local environmental resources, including recyclable or repurposed materials, to create an engaging and developmentally supportive learning space (Kementerian Pendidikan Nasional Republik Indonesia, 2009).

The environment, as expounded by Sikandar (2015), constitutes the nexus where situations and conditions intersect with personal needs and objectives, thereby engendering lifelong experiences. Sikandar identifies three primary environmental realms: the family, the school, and the community. It is imperative to introduce children to these spheres to instil in them an understanding that they coexist with others and do not lead solitary lives. Children must learn to recognize individual uniqueness and develop an appreciation for both similarities and differences. In line with this, Malaguzzi, the founder of the Reggio Emilia approach, refers to the environment as the "third teacher." Accordingly, in Reggio Emilia schools, the environment is intentionally designed, flexible, and capable of shaping children's identities as influential participants in their own lives and in the lives of others (Biermeier, 2015). Complementing this view, Maria Montessori emphasizes the role of the "prepared environment," where both teachers and children are mutually influenced by their learning surroundings. The educator's role involves careful observation and the continuous adaptation of the environment in response to the child's needs.

A lack of knowledge among teachers regarding the existing local culture in the Lebak region presents significant challenges in selecting appropriate materials to introduce to children. This limitation also contributes to the exclusion of local cultural content from the curriculum and its minimal integration into early childhood education practices. It is essential for every teacher to possess sufficient cultural knowledge to effectively introduce local traditions and practices to young learners. Such knowledge serves as the foundation for delivering information and also facilitates the transmission of values, attitudes, and skills relevant to children's holistic development. In culturally diverse school settings, new teachers are expected to acquire and apply a range of competencies that enhance cultural adaptability and deepen their understanding of varied cultural constructs (Salmona et al., 2015).

To ensure teachers possess adequate cultural competence, professional development and training focused on local culture are crucial, particularly for novice teachers or those relocating from different regions. Integrating a local

culture-based learning model into teacher education programs can significantly enhance pre-service teachers' instructional capabilities (Widada et al., 2019). Teachers who are well-equipped with such knowledge can facilitate cognitive development in children, including conceptual understanding (Herawaty et al., 2018), symbolic representation (Widada et al., 2019), and problem-solving abilities (Iswinarti & Suminar, 2019), as well as improvements in early literacy skills such as reading (Ratminingsih et al., 2020). Another strategic effort to enrich teachers' cultural understanding involves fostering partnerships between preschools, families, and the wider community. Effective communication between parents and teachers can provide a foundation for the development and implementation of local culture-based curricula. In this context, parents of young children act as valuable educational resources in the integration of local cultural knowledge into early learning environments (Shih, 2022).

Strategy for introducing local culture in learning

Based on the preceding discussion, it is evident that the majority of teachers have incorporated elements of local culture into the learning process. Two thematic areas that are most frequently employed to facilitate this cultural introduction are “My Environment” and “My Country.” The specific strategies utilized by teachers—encompassing the selection of materials, learning activities, instructional methods, and educational media—are summarized in the table below.

Table 2: Learning Components and Cultural Integration

Themes/ Sub-themes	Introduced culture	Activity	Method	Media
My Environment	Traditional Food	Make “cilok”	Hands-on practice	Ingredients for making cilok
		Making traditional cake	Question and answer; bringing the cake as a medium	Leaves, bananas, flour and cooking utensils
		Coloring of traditional food picture	Tell a story	picture
	Traditional game	visit to the “emping” making place	Hands-on practice	picture, video
		Playing of traditional game	Hands-on practice	There isn't any
		Playing of congklak	learning	Question and answer
		Drawing, coloring, stick engklek	picture	picture
	Traditional house		Hands-on practice	chalk to make pictures of hopscotch, gobak, broken roof tiles for gaco
		Playing of oray-orayan	Hands-on practice	Teacher and child
		Colorful traditional bamboo house	Coloring pictures of traditional houses	crayon

My country	Traditional clothes	Coloring and sticks	listening	Paper, scissor, glue
		Coloring of saung baduy	Questions and answers and demonstrations	Baduy saung drawing, and colored pencils
		Traditional use clothing activities	Questions and answers and assignments	clothes
	Traditional food	Introduction to how to make batik	Story and visuals	Picture
		Tell a story	Tell a story	Picture
		Make regional specialties	direct practice methods, storytelling and question and answer	Videos and picture
	Traditional clothes	coloring pictures, tasting food	Picture and traditional food	Crayons and food
		Drawing, coloring, connecting pictures	Question and answer method, demonstration method, field trip	Visual and audiovisual media
		Wearing various traditional clothes	Hands-on practice	Traditional clothes
	Traditional game	Coloring	Storytelling method	Mobile media
		Fortification game (Permainan bentengan)	Play	Tell a story
		The ankle game (Permainan engkle)	Hands-on practice	Storybook
	folklore	Play marbles	Play	Marbles
		Tell stories and practice	Storytelling method	Magazine
		Tell a story	Tell stories about local culture, for example folklore	Media dolls in traditional clothing in the Banten region
	Traditional house	Drawing, coloring, connecting pictures	Question and answer method, demonstration method, field trip	Visual and audio visual media
		drawing houses and coloring	buku cerita	worksheets, notebooks

The data in Table 2 indicate that across both themes, “My Environment” and “My Country,” there are recurring cultural elements introduced to children, including regional foods, traditional clothing, traditional games, and traditional houses. However, folklore appears exclusively within the “My Country” theme. In terms of learning activities—particularly those related to traditional foods and games—teachers have made efforts to provide real, tangible materials during instruction. This hands-on approach allows children to observe, touch, and practice directly, thereby enhancing their sensory experiences and cultural understanding. For instance, when introducing local foods such as *cilok* or traditional cakes, teachers incorporate authentic materials such as banana leaves, flour, and cooking

utensils. These materials not only familiarize children with the ingredients but also enable them to engage in the preparation process, thus fostering a deeper appreciation of the cultural significance behind these items. Such strategies have been shown to spontaneously capture children's attention and promote meaningful understanding of the complex knowledge embedded in their local environment.

In contrast, when introducing traditional houses, teachers employ activities such as drawing, coloring, connecting, and pasting images, utilizing media such as crayons, colored pencils, and worksheets. The methods implemented to convey local cultural content include question-and-answer sessions, hands-on practice, storytelling, and field trips. Among these, questioning is frequently employed as a means to assess children's understanding. Through this method, teachers communicate specific cultural knowledge and subsequently pose questions to evaluate whether the children have accurately grasped the information. The responses provided by the children reflect their cognitive abilities, particularly in processing and internalizing new knowledge. This process highlights the presence of active interaction and communication not only between teachers and students but also among the children themselves. Such interaction aligns with one of the key features of John Dewey's educational theory. As cited by (Dar, 2021), Dewey emphasizes that interaction and communication, when centered on fostering and deepening shared meaning, significantly enhance learning and developmental outcomes. In this context, children are afforded opportunities to consider, integrate, and engage with the perspectives, ideas, and experiences of their peers, thereby promoting collaborative meaning-making within their groups.

Essentially, early childhood education offers various avenues for preserving the cultural heritage of Lebak. A range of methods and media can be leveraged to cultivate children's curiosity while simultaneously minimizing monotony in the learning experience. This finding is consistent with prior research highlighting the effectiveness of game-based, conversational, and literary text-oriented approaches in teaching local culture (Kanoksilapatham, 2020; McCarthy & Goldman, 2019). Among these, storytelling—particularly in the form of folklore—emerges as a strategic pedagogical tool. Das and Chhaparia (2023) underscore storytelling as a powerful medium that connects generations through cultural narratives, thereby strengthening cultural resilience and fostering early awareness. Traditional clothing also constitutes a key component of local cultural content introduced to children. As emphasized by Adepeko et al. (2023), the early introduction of traditional attire plays a critical role in its preservation, serving not only as a symbol of cultural identity but also as a medium for self-expression and social cohesion.

Thematic learning serves as an overarching framework through which knowledge, attitudes, and skills are developed in early childhood education. Instructional content is typically delivered prior to the activity, allowing subsequent tasks to reinforce prior knowledge and cultivate positive attitudes toward the subject matter. In this context, data from the study revealed that 66% of educators introduced elements of local culture during the apperception phase—an instructional strategy aimed at connecting children's prior knowledge with new concepts. Conversely, 30% of respondents reported initiating activities without any prior introduction to the material. Apperception, as a pedagogical approach, is critical for activating existing cognitive frameworks and ensuring meaningful learning. The absence of such preparatory engagement can hinder children's

understanding, resulting in rote participation devoid of contextual comprehension. As Liu (2015) highlights, one of the core competencies of effective educators lies in their capacity to analyze and adapt teaching practices to students' specific sociocultural contexts. This task becomes particularly complex when educators are working with learners from diverse ethnic, cultural, or racial backgrounds. Similarly, Vermunt (2014) argues that facilitating student learning that is active, meaning-oriented, self-regulated, and collaborative imposes increasingly demanding and multifaceted roles on teachers

To enhance not only children's learning outcomes but also their sense of self-efficacy within the learning process, educators must intentionally foster self-regulation skills (Zaki, 2018). In line with this, Ki Hajar Dewantara emphasized that education is fundamentally about guiding the intrinsic potential of each child, enabling them to achieve personal well-being and social harmony (Anwar et al., 2020). Consequently, early childhood educators are required to engage in ongoing critical reflection, assessing whether their pedagogical strategies align with the core principles of early childhood education. Such reflection must take into account the developmental stage of the child, the sociocultural demands of the time, and the extent to which learning experiences are both meaningful and enjoyable—thereby nurturing a sustained interest in learning. This reflective and child-centered approach echoes Ki Hajar Dewantara's educational philosophy, positioning learning as a holistic endeavor rooted in the child's context. Furthermore, as Dewey (as cited in Sikandar, 2015) emphasized, teachers—recognized as key agents within the learning community—play a pivotal role in shaping and directing educational experiences.

Conclusion

Educators in Lebak, Banten, Indonesia, exhibited a strong familiarity with their local cultural heritage, encompassing traditional foods, games, clothing, architecture, and folklore. In classroom settings, a variety of pedagogical strategies—such as experiential learning, interactive discussions, and storytelling—were employed to introduce these cultural elements. These strategies were further enriched by the use of diverse media, including physical artifacts, educational videos, and art tools, to enhance student engagement and participation. Despite the widespread incorporation of cultural content in instructional activities, the formal integration of local culture into curriculum documents and lesson planning remained limited. This discrepancy highlights a disconnect between pedagogical practices and curriculum development, which stands in contrast to the national directive mandating the inclusion of local wisdom in early childhood education. The findings point to an urgent need for stronger institutional support and focused professional development to enable educators to systematically embed cultural content into instructional planning. Intentional planning for cultural education not only demonstrates teacher preparedness in transmitting cultural values but also cultivates children's appreciation for, and emotional attachment to, their cultural and national identities.

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EDUCATIONAL MODEL FOR ELEMENTARY SCHOOL IN KETAPANG

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Received: 31 October 2025; Accepted: 25 November 2025

Abstract

Ketapang is one of the 3T areas (outermost, foremost, lagging), a district in West Kalimantan Province. Ketapang Regency faces many problems, including economic, social, infrastructure, health, and educational issues. In the field of education, many problems are faced by both teachers and students in implementing learning. This study aims to reveal the current state of education and identify suitable learning models for the Ketapang area, particularly in the interior. The research location covers the northern, central, and southern parts of Ketapang. The data sources in this study included priests, teachers, students, and parents. Data were obtained through interviews, documentary studies, and observations in the three regions. The data analysis used included 1) reduction of the data obtained, 2) presentation of the data, and 3) drawing conclusions. The study's results suggest that the ideal educational framework for Ketapang Regency should focus on fostering educators' empathy and sincerity, employing media to boost student understanding, rewarding students, and ensuring educators enforce discipline to enhance learning effectiveness.

Keywords: 3T areas, educational model, elementary school, Ketapang

Introduction

Education in Indonesia has complex challenges that need serious attention from interested parties (Ansar et al., 2021). These challenges will directly or indirectly affect the quality of education. One of the challenges faced is the uneven distribution of technology used in schools. Access to information through information technology today is indispensable for the learning and teaching process (Maritsa et al., 2021). In addition, the uneven quality of teachers is one of the factors that affects the quality of education (Handayani & Sukari, 2024). Not all teachers have equal pedagogical, social, professional, and personality competencies (Lestari & Purwanti, 2018). Uneven school facilities (Sukari & Munzillah, 2025) exacerbate this condition. Some of these inequalities show the gap in education development in Indonesia.

On the other hand, education is an important foundation in the knowledge, formation of attitudes, and character of students (Nurfadhila et al., 2025). Basic education plays a role in instilling attitudes and values in life from an early age. In the 21st century, the demands on students' abilities are getting heavier. Students are expected to possess critical thinking, problem-solving, metacognition, communication, collaboration, innovation, creativity, and normative literacy skills



(Madhiyah et al., 2021). The demands of life skills in the future are expected to be fulfilled in the educational process.

As the frontline of education, teachers must meet the requirements for teacher qualifications. According to Law Number 14 of 2005, one of the requirements to become a teacher is that teachers must have social, pedagogic, personality, and professional competence. In order to be able to train students' life skills, teachers need to have creativity to choose learning strategies and media that are suitable for their students (Rimayasi, 2024). The right learning strategies and media can increase students' motivation to learn.

Learning carried out by teachers also needs to accommodate the characteristics of students so that teachers can apply the right learning models according to the needs of students. Varied learning will arouse interest and motivation to learn. The application of these learning models also needs to be adjusted to the purpose of the subject matter (Purnomo et al., 2022). The right learning model will stimulate student engagement and intelligence.

Improving the quality of teachers is carried out through various trainings, supervision, workshops, seminars, and so on (Fatimah et al. 2025; Noviyantika 2021; Zulhimma, 2015). Improving the quality of teachers is also carried out through the Teacher Professional Program (PPG), both pre-position and in-office. In this era of digital transformation, training is not only carried out in theory but also in practice using learning applications, both free and paid. Learning based on technological advances will make it easier for students to learn complex things (Ambarwati et al., 2021). In other words, students are more likely to accommodate and assimilate knowledge.

Improving the quality of teachers aims to improve the learning model that has been carried out so far. Conventional learning is more teacher-centered, learning is very abstract, not based on the realities of life, tends to focus on specific areas, student learning time is mostly used to work on assignments, and practice questions (Purnomo et al., 2022). By participating in training, teachers are expected to change the teaching pattern that has been carried out so far. This is in line with the opinion of Kaudfeldt (2005), who states that teachers' learning patterns need to be adjusted to each student's brain. In addition, teachers need to provide real experiences that activate students' five senses.

Ketapang Regency is one of the districts in the province of West Kalimantan. The majority of the population of Ketapang district consists of Dayak, Malay, Chinese, and Javanese ethnicities. The total population of Ketapang district is 599,900, with 46,590 poor people and a Human Development Index of 70.34 (BPS Kabupaten Ketapang, 2025). The majority of the people work as laborers/employees because in the Ketapang district, many lands have changed their function to oil palm plantations and bauxite mines. In addition, Ketapang district has varied geographical characteristics, such as coastal areas (7 sub-districts) and upstream areas (13 sub-districts). Some areas are difficult to reach by motorized vehicle and must be reached on foot.

In general, some of the problems that exist in Ketapang include economic disparities, low-quality infrastructure, and education. Economic disparities occur because some communities have oil palm plantations and others do not. Oil palm plantation owners have better economic conditions than those who do not. In addition, economic development occurs in certain areas (not even). Infrastructure

improvements are still limited, including school infrastructure. This limitation is one of the obstacles to improving the quality of education. For education issues, education in Ketapang is still categorized as lagging compared to other regions.

The education problems faced in Ketapang district include accessibility, quality of educators, the condition of facilities, and infrastructure. This condition is one of the reasons why education in the Ketapang district is left behind. The data also shows that in 2021, the average length of school (RLS) was 7.46 years, while in 2022, it was 7.48 years. Meanwhile, the School Lama Expectation (HLS) in 2021 was 11.81, and in 2022 it rose to 11.95. This data shows that access to education has increased, albeit still relatively small.

Elementary school education in the Ketapang district faces various significant challenges, including accessibility, the quality of educators, and the condition of educational infrastructure. The latest data shows that there are still 17,577 school-age children who are not registered in the formal education system, which is a serious obstacle to the equitable distribution of education in this area (Kementerian Pendidikan Dasar dan Menengah, 2025). This requires special attention from local governments and all stakeholders so that the right to basic education for all children can be fulfilled optimally.

In addition to access issues, the quality of learning in Ketapang elementary schools is the main focus that needs to be studied. The implementation of an effective learning model in accordance with the local context plays a very important role in increasing student participation, learning motivation, and learning outcomes. An integrated thematic learning model based on a scientific approach, such as that applied in several primary schools in Ketapang, shows an effort to integrate various subjects with methods that emphasize students' observation, reasoning, and communication activities. This approach has the potential to increase students' active involvement and develop critical thinking skills according to regional characteristics and 21st century learning needs.

However, the implementation of the learning model still faces a number of obstacles, including limited learning media, differences in students' abilities and interests, and the deployment of teachers who still have to adapt to the new approach. On the other hand, support for facilities and infrastructure, teacher assistance, and parental involvement are very important supporting factors in realizing effective learning. Therefore, in-depth research on the primary school learning model in Ketapang is very important to identify best practices, barriers faced, and strategic recommendations to support improving the quality of basic education in the region. By paying attention to these various aspects, this paper aims to examine the learning model applied in Ketapang elementary schools holistically, explore its effectiveness, and contribute innovative solutions that can be adapted to overcome educational challenges in this area.

Method

This research is qualitative and explores the opinions of research subjects on the phenomenon of education in the Ketapang district. The subjects in this study include priests, teachers, and students from State Elementary and Catholic Elementary Schools in six villages. The research subjects were allowed to answer or not answer the oral questions presented freely. The focus of this research is the challenges faced by teachers in learning and the teaching models that suit the

conditions of elementary school students in Ketapang. Interviews were conducted across six villages: Terusan, Serengkah, Randau, Menyumbung, Botong, and Balai Semandang. Terusan Village represents the southern region, Serengkah the eastern, Randau and Menyumbung the central regions, and Botong and Balai Semandang the northern region. The regional divisions follow the territory boundaries established by the Diocese of Ketapang. Data were collected through observation, documentation, and interviews with the research subjects. Data analysis was performed using the steps proposed by Miles et al. (2014), which include: 1) condensing the collected data, 2) presenting the data, and 3) describing and verifying the conclusions. The data obtained were validated using source triangulation. In the validation of these sources, the researcher compares the opinions of various sources (Alfansyur & Mariyani, 2020).

Findings and Discussion

The People of Ketapang Regency

Ketapang Regency consists of 20 sub-districts. The Catholic Church divides Ketapang district into five regions, namely the northern region, the Central region, the western region, the eastern region, and the southern region. The villages used as samples in this study include the villages of Terusan, Serengkah, Randau, Menyumbung, Balai Semandang, and Botong, which have different regional and school conditions. The road infrastructure to reach these areas is quite difficult except in Randau and Balai Semandang. Internet access in the six regions is difficult, including in schools. Easy internet access is in the center of the sub-district and parish pastorate that uses the Starlink network.



Figure 1. Ketapang Regency Area
Source: <https://keuskupanketapang.org>

In terms of ethnicity, the people in Ketapang district are heterogeneous. The existing tribes living in Ketapang district consist of Dayak, Malay, Javanese, Chinese, and NTT tribes. Most Dayak tribes live in the interior, while other tribes are closer to urban areas, especially the Malays and Chinese. In terms of religion,

the majority of the people of Ketapang regency are Muslims, followed by Catholics, Christians, Hindus, Buddhists, and Confucians. They coexist in harmony in the midst of ethnic and religious diversity.

In general, the people of Ketapang depend on the plantation sector, especially oil palm and rubber, as well as agriculture and fisheries. In addition, the bauxite mining sector plays a significant role because Ketapang is one of the main bauxite producers in Indonesia, which has the largest alumina processing plant in Southeast Asia. There are also not a few Ketapang people who work as traders, civil servants, educators, and workers in educational and social foundations.

Education

In addition to the government, education providers in Ketapang district are carried out by foundations. In Ketapang district, there are 229 foundations engaged in education (Kementerian Pendidikan Dasar dan Menengah, 2025; Yulianti et al. 2025). These foundations are based on Catholicism and non-Catholicism. For example, the USABA foundation (a foundation belonging to the diocese of Ketapang), the Pangudi Luhur foundation (a foundation owned by the FIC Brothers), the Fatima Love Service foundation (a foundation belonging to the Order of Saint Augustine), the Al-Muhajiri Islamic Boarding School foundation, the Hidayatullah Foundation, the Al Mujahidin Foundation, and so on.

The Diocese of Ketapang has four dreams for the foundation of Catholic education providers related to education in Ketapang, especially in the Usaba foundation. These dreams emerged from an interview with UKTP. The four dreams are first, education in Ketapang is directed to *non multa sed multum*. Education should not pursue a lot of knowledge, but deep knowledge. Second, school is a community of love that is followed by solidarity and reflectivity. It is intended that relationships between individuals are based on the same personal dignity as human beings. Third, one school, one product. Schools are expected to explore the school's potential to produce something. Fourth, there is a Usaba day every Saturday. On Saturday, every class, teacher, and student does a good job by cultivating local wisdom in the school.

In the context of the educational curriculum, there are still many schools that apply the 2013 curriculum as a reference in the learning process. One of the reasons is the teacher's understanding of the Independent Curriculum, which is still minimal, especially the deep learning approach. The concept of deep learning emphasizes a deep understanding of the material and students' ability to apply it in everyday situations or in new contexts (Kemendikdasmen, 2025).

The challenge of implementing the Independent Curriculum in Ketapang is closely related to the limitations of adequate technology infrastructure and human resources. Unstable internet access and digital devices are the main obstacles faced by schools, especially in rural and remote areas. Geographical conditions that make it difficult to reach technology services make it difficult for many schools to utilize technology as a support for modern learning, which is the core of the Independent Curriculum. As a result, the project-based learning process and independent approach that requires the use of technology becomes hampered and less than optimal.

In addition, the limitation of human resources, especially teachers' competence in operating technology and running a more flexible learning model, is

also a serious challenge. Many teachers have not received adequate training to implement the Independent Curriculum effectively, so the motivation and ability to implement innovative learning methods have also decreased (Yulianti et al., 2025). The high administrative burden on teachers further reduces their time and focus to adapt to this new curriculum

This challenge requires concrete efforts in the form of improving the quality of technological infrastructure in schools, intensive teacher training and mentoring, and administrative support so that teachers can focus more on the learning process. This effort is important so that the implementation of the Independent Curriculum can run in accordance with its main goal, which is to facilitate independent, creative, and potential-based learning of students.

Student Learning Situation

From the six villages, students felt happy when they carried out activities in groups. If individually, students do not have the courage and confidence. Most students feel embarrassed and awkward when meeting new people. This was revealed from a joint interview with PVKT, who said, "Students here are embarrassed when they meet other people". They tend to avoid meeting new people. This was also revealed in an interview with SSBS, who said that "the most preferred activities are tutoring (tutoring) and outbound".

Tutoring and outbound activities are carried out after the learning is over. This activity was initiated and accompanied by students who participated in service learning in Ketapang. The students were enthusiastic about participating in this activity because of activities outside of school, such as tutoring and outbound. Tutoring and outbound activities were carried out in a relaxed but serious manner. Students accompany students with various learning methods that are adjusted to the level of student development.

In the tutoring carried out, students are often rewarded. The rewards given can be simple food, giving stars, reinforcement with words, or giving a check mark (✓) to the student's work. Students feel happy and proud when students give rewards. Observations made show that there are students who 'protest' to the tutor when their work has not been checked. SSRD said, "sis, why haven't I been given a checkmark?"

Based on the observations made, the learning atmosphere during tutoring is different from learning at school. During tutoring, students do tutoring in a relaxed and cheerful manner. However, when students study in school, the atmosphere is relatively serious and less relaxed. This can be since the learning process carried out by teachers tends to be more teacher-centered and less student-centered.

Even though the learning atmosphere took place in a relaxed and intimate manner, the students still showed a disciplined attitude and close attention to the explanations given by the students participating in service learning. This condition shows that a non-rigid learning atmosphere can create a conducive environment for students to receive material better. According to constructivist learning theory, a comfortable and participatory atmosphere allows students to be more active in building their own knowledge (Piaget 1972; Vygotsky 1978). In this context, the service-learning approach not only provides a learning experience for students but also fosters student motivation to learn at partner schools.

In addition, students' interest in learning activities guided by students participating in service learning shows that there is a positive interpersonal relationship between teachers and students. A harmonious relationship between teachers and students is an important factor in creating an effective learning climate. According to Hamalik (2018), the success of the teaching-learning process is greatly influenced by the ability of educators to build open, empathetic, and respectful communication with students. In service-learning activities, egalitarian interactions between students and students help create a sense of mutual trust and respect, so that students can more easily follow the directions given.

However, the aspect of firmness and clarity in giving orders remains a determining factor for the success of learning. An educator, including students participating in service learning, needs to show a firm attitude so that students understand the limitations and responsibilities in the learning process. Clarity of instruction helps students to focus and understand what is expected of them in each learning activity. Clarity in the delivery of goals, commands, and directions is one of the important components in the effectiveness of learning (Sudjana, 2017).

In the learning process in the classroom, students feel afraid of the teacher. An interview with GRTR revealed: "If this time it is indeed. It means that the environment has been formed. So, the language is a bit rough. So, the children sometimes feel afraid. On the other hand, the presence of students gives another color; they greet students in a friendly manner. This makes students not afraid and close to each other.

Learning by Teacher

The curriculum enforced in elementary schools in the Ketapang district has not fully used the Independent Curriculum. Some schools are still using the 2013 Curriculum. This is understandable considering that the location of the inland area is difficult to reach and the facilities and infrastructure are inadequate. In addition, teachers have not received training on the Independent Curriculum. This was revealed during an interview with GRBT. He said, "The Independent Curriculum is only implemented in grades 1 and 4".

Teachers have the will to improve the quality of learning. Teachers hope that there will be many trainings that can improve teachers' ability to teach and increase teachers' creativity. In a meeting with teachers in Menyabung village, it was revealed that they need training related to learning both strategies, media, evaluation, and material deepening. Likewise, in Terusan, the teacher revealed, "So, through the program, we will understand each other, provide understanding between teachers. In the form of a working group of school principals, teacher working groups. As such, it was held at "SD Induk", Kemuning. For example, a new program comes, so these teachers are called to be trained for at least 2 days or three days.

Some teachers who serve in rural areas do not have adequate competence in the field of teaching, which is their duty. Some of them are still attending lectures at the Open University to complete their undergraduate studies, which shows that their field of study background was not completed before teaching. Furthermore, some teachers teach subjects outside their field of expertise. This condition shows that there is a gap between the field of study and the teaching tasks undertaken, which has the potential to affect the quality of the learning process.

The diversity of teacher competencies in disadvantaged, frontier, and outermost (3T) areas, especially in the Ketapang area, is relatively high. There are teachers with an adequate pedagogic understanding and academic background, but on the other hand, there are also those who still need intensive assistance in developing their competencies. KSTR revealed that "there are still teachers who have not yet completed S1". Variability like this poses quite serious challenges to improving the equitable distribution of the quality of education. In the context of education in remote areas, the equitable distribution of teacher competencies is one of the key factors so that all students have the right to equal educational services.

In addition to the aspect of teacher competence, supporting facilities for the learning process are also still a significant obstacle. The books used by the teaching staff are mostly outdated and less relevant to the current curriculum development. Based on an interview with KSBT, it was stated that "the books we have are books of the 'prophet's era, sometimes shabby, and we take care of them". Likewise, GRTR stated that "for teachers, books are still lacking. There are no books, there are only a few". The same thing was also revealed by GRRN, who had to look for books in Pontianak because they could not expect books from the school. This reality indicates that learning resources are still very limited and do not support dynamic learning. In this case, improving learning facilities and infrastructure for teachers and students in schools in the 3T area is very important to motivate all school residents and strengthen the learning ecosystem.

Learning media in rural areas is also still very lacking. Teachers rarely use learning media, including laptops. Not all schools in the interior use computer technology (laptops). This is constrained because not all teachers have computers, and the internet does not exist. Even if there is, the internet in the interior is not smooth.

Furthermore, the implementation of the Independent Curriculum in six villages has not been running optimally. One of the main obstacles faced by teachers is that they do not fully understand how to prepare the curriculum tools. This was expressed by GRTR as stated, "Well, I don't understand that. It uses the Independent Curriculum. I don't understand yet; it hasn't stopped there; the meeting has never been held by the Teacher Working Group (KKG). I still hold K-13".

This condition shows the need for intensive training and continuous mentoring for teachers in the 3T area so that they can understand and effectively implement the Independent Curriculum. By understanding the series of preparations ranging from CP → TP → ATP → Teaching Modules, teachers can design learning that is more contextual, structured, and relevant to the characteristics of students. As mentioned in the guidelines, the Teaching Module is a device that contains a series of materials, learning activities, and assessments developed based on ATP. In the learning process in the classroom, teachers rarely practice. Teachers give more explanations to students without associating the lesson with daily life. In addition, the learning process is carried out without providing direct experience.

Educational Model

Basic education is an important foundation in the formation of students' character, knowledge, and skills. Elementary school plays a role as the initial stage to instill literacy, numeracy, and socio-cultural values that are provisions for

success at the next level of education. Therefore, education needs to be adjusted to the characteristics possessed by students.

Education in elementary schools, especially in Ketapang district, needs to be done with heart. Education in rural areas, with existing limitations, not only focuses on academic achievement but also shapes and nurtures the character of rural communities, instilling moral values and the emotional well-being of students. Educating with heart means emphasizing the human relationship between teachers and students.

Local culture also needs to be raised in the classroom learning to reveal students' experiences in the classroom. For example, the culture of *Nyandau*. *Nyandau* means waiting for the durian to fall. This culture is spread, especially in West Kalimantan. Durian trees should not be cut down, climbed, or trimmed with branches. Therefore, people get durian when the durian falls to the ground. The fallen durian was contested by the people who were waiting for it. *Nyandau* can be integrated in subjects, one of which is IPAS with the topic of Getting to Know the Surrounding Environment. Teachers can create teaching modules based on predetermined learning outcomes.

The cultural factors raised in learning can also be used as a means to implement the Independent Curriculum with an in-depth learning approach. In today's learning, it is also known as the culturally responsive teaching (CRT) approach. In deep learning, teachers integrate the cultures around students in learning (Fitriah et al., 2024). By linking this culture, learning is expected to be easier for students to accept. On the other hand, this culture-based learning will hone students' affective skills to build a sense of solidarity, mutual respect, and respect for their culture.

The problem that needs to be solved immediately is to make the teacher understand how to make a teaching module. Teachers need to prepare teaching modules by adjusting the conditions, situations, character of students, culture, and so on. The preparation of teaching modules is not simple. Teachers need to take the time to think about how the specified learning outcomes can be achieved by integrating local values/culture.

Based on the data above, students can better understand the subject matter if the teacher uses learning media. This shows that the role of media in the learning process cannot be ignored because it helps students relate abstract concepts to concrete things. Learning media functions as an intermediary between teachers and students so that messages or materials can be conveyed more clearly and interestingly. When students see, hear, and interact with the media, they have an easier time understanding and remembering the material being presented. Thus, learning media serves as a bridge between abstract material and real experiences that can be observed by students (Arsyad, 2020).

This is in line with the opinion of the Titin et al., (2023) which states that suitable learning media will make it easier for students to understand the subject matter. The selection of the right media does not only depend on the availability of facilities and infrastructure, but also on the teacher's ability to adapt the media to the characteristics of students. For example, for elementary school students, illustrated media or interactive animations are more effective than long texts, as they can attract attention and motivate them to study actively.

In addition, teachers can innovate by creating learning media that is tailored to the topic being discussed. Teacher-made media is usually more contextual because it is developed according to environmental conditions and the needs of students in the classroom. For example, teachers can create technology-based media such as educational videos, interactive quizzes, or simple apps that students can access independently. Teachers can also innovate by creating learning media that are in accordance with the topic being discussed. Homemade media is usually more contextual and relevant to the students' learning environment, as it is adapted to the real conditions around them. For example, teachers can create simple learning videos, educational games, or technology-based interactive activity sheets. With the creativity of teachers, learning media is not only a tool, but also a means to create a fun and meaningful learning atmosphere for students.

The data above also shows that students will have more enthusiasm if they are given awards or praise. Giving awards and praise is a form of positive reinforcement that is very effective in increasing learning motivation (Febianti, 2018). When students feel that their efforts and learning outcomes are rewarded, they will be more eager to repeat those positive behaviors. According to Santrock (2021), student motivation can grow when teachers reinforce the form of appreciation, because it creates a feeling of pride and increases students' confidence in their abilities.

In addition, awards and compliments don't always have to be material gifts, but they can be in the form of verbal acknowledgments, certificates, or even just a thank you and a smile from the teacher. This simple form of appreciation is able to have a great psychological impact on students. Uno, (2020) explained that giving the right awards can foster a sense of competence and commitment in students in the learning process. Thus, students will be more motivated to achieve higher achievements because they feel appreciated for the efforts they have made.

Furthermore, the awarding of rewards and praise is also related to the behavioristic motivational theory put forward by Skinner. According to this theory, a person's behavior can be formed through reinforcement. In the context of education, teachers can use praise as a positive reinforcement to reinforce desired learning behaviors (Slavin, 2019). When students receive praise for their work, it reinforces active and disciplined learning behavior, as students will associate success with positive responses from teachers.

However, teachers also need to be careful in giving awards and praise so as not to cause dependence on external motivation. According to Ryan and Deci, (2020) In Self-Determination theory, motivation that is too dependent on external factors can hinder the development of students' intrinsic motivation. Thus, praise should be given proportionately and accompanied by encouragement to cultivate motivation from within the students themselves. For example, a teacher could say, "You've put in a lot of effort, keep your enthusiasm for learning," so that students understand that rewards are given because of the learning process, not just the end result.

On the other hand, learning for students in Ketapang can run well if the teacher is firm during the learning process. Teacher firmness is one of the important aspects in creating discipline and a conducive learning atmosphere in the classroom (Kinesti et al., 2021). A firm teacher can direct students to obey the rules and respect the learning process without causing fear. According to Djamarah and Zain (2020),

teacher assertiveness is a form of control needed so that teaching and learning activities take place effectively and in an orderly manner, so that learning goals can be achieved optimally.

In addition, the teacher's assertiveness also plays a role in shaping the character of students to be more disciplined and responsible for their tasks. Teachers who are consistent in applying the rules will encourage students to understand the boundaries of acceptable behavior in the school environment. This is in line with the (Hamid, 2021) opinion, which states that the teacher's assertiveness helps build a positive learning climate because students feel that there is certainty and fairness in the learning process. Thus, students will appreciate the teacher more and be motivated to follow the lessons well.

Furthermore, assertiveness does not mean harsh or authoritarian, but rather shows a consistent, fair, and authoritative attitude in managing the class. Teachers who are assertive but still respect students can foster mutual respect and create healthy interactions in the classroom. According to Sardiman (2020), teachers who have a firm and empathetic attitude will be more successful in directing student behavior because they can balance discipline and attention to the emotional needs of students. Therefore, the firmness of teachers in Ketapang is one of the keys to success in improving the quality of learning in schools.

Conclusion

The recommended education model for disadvantaged, frontier, and outermost (3T) areas, especially in Ketapang Regency, emphasizes the implementation of the learning process based on empathy and the sincerity of educators. Learning is carried out by using relevant media to improve students' conceptual understanding. In addition, giving awards in the form of praise is used as a motivational strategy, while educators' assertiveness plays an important role in creating discipline and effectiveness of the learning process.

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THE INFLUENCE OF SOCIAL MEDIA ON BEHAVIOR AND CHARACTERISTICS OF TEENAGERS

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Received: 31 October 2025; Accepted: 25 November 2025

Abstract

Social media use in the current digital era is widespread among all groups, especially teenagers. Social media certainly influences the behavior and characteristics of its users, both positively and negatively. This paper aims to examine the effects of social media use on the behavior and characteristics experienced or acquired by adolescent users. This paper was conducted using a literature review method sourced from several journals and articles circulating online. The results of several journals and articles regarding the influence of social media on the behavior and characteristics of adolescents indicate that social media has both positive and negative effects. Some positive effects include expanding friendship networks, improving communication skills, and serving as a forum for interpersonal discussion. Some negative effects include making adolescents addicted to social media, leading to cyberbullying, and triggering deviant behavior. Based on the literature review, it can be concluded that social media does indeed have both positive and negative effects on the behavior and characteristics of adolescent users. Positive effects include improving communication skills and expanding relationships, while negative effects include addiction and triggering deviant behavior.

Keywords: behavior, characteristics, influence, social media, teenagers

Introduction

The digital era has brought many changes and developments to life, particularly in the field of information technology. Social media is one of the most significant and widely used developments in information technology, utilized by everyone from young people to adults. According to data from We Are Social, as of January 2025, approximately 143 million people in Indonesia use social media, with the highest number of users falling within the 18-34 age range. This phenomenon demonstrates how social media has become an inseparable part of social life for Indonesian society, especially for the younger generation.

Social media is a digital platform that enables individuals to communicate and interact with other users virtually. In the past, human interaction was limited to face-to-face meetings and direct communication. Now, geographical and time constraints are no longer barriers. A person can connect with anyone, at any time, and from anywhere with just the touch of a finger. However, this ease of access and high intensity of social media use bring complex consequences for the formation of



individual behavior and characteristics, especially among the younger generation or teenagers who have grown up as digital natives (Boyd & Ellison, 2007).

Adolescence is a critical phase in the formation of personality, values, and social skills. During adolescence, individuals begin to develop self-concept, explore identity, and develop critical thinking skills. However, the presence of social media has created a complex new developmental environment, where the boundaries between the real and virtual worlds are increasingly blurred. Constant exposure to content, pressure to keep up with trends, and an instantaneous digital culture have raised important questions about how social media actually influences adolescent character and behavior.

Social media use by adolescents has complex and multifaceted impacts. On the one hand, social media provides opportunities for adolescents to connect with friends, express themselves, and access information. However, on the other hand, excessive use can lead to various psychological and social problems, including addiction, cyberbullying, and unwanted behavioral changes. Recent research shows that cyberbullying is becoming a widespread phenomenon among Indonesian adolescents, with a prevalence reaching over 60% among social media users (Marsinun & Riswanto, 2020).

This paper aims to further explore the influence of social media on adolescent behavior and characteristics through a literature review. By analyzing various scientific journals and research articles, this paper will identify the positive and negative effects of social media on adolescents. Through this review, it is hoped that suggestions can be provided to consider the choice of attitudes in using social media so as to minimize its negative impacts and be able to utilize social media well.

The Positive Influence of Social Media on Teenagers

Social media offers significant benefits for adolescents' social and personal development. One of the most prominent positive influences is the expansion of their social network. Through social media, adolescents can connect with friends from diverse geographic and cultural backgrounds, without the constraints of time or place. This global connection allows adolescents to build meaningful friendships with individuals who share similar interests and values.

Social media has many benefits for adolescent development, both socially and personally. Expanding friendship networks is one of the most prominent positive effects of social media use. Teenagers using social media can connect with friends from diverse cultural and geographic backgrounds without the constraints of time or place. They have the opportunity to build meaningful relationships with people who share their values and interests through social media.

Social media is also useful for helping teenagers improve their communication skills. Teens learn to express their ideas clearly and persuasively through interactions with posts, comments, and messages. They also learn to understand others' opinions through discussions and debates on social platforms. This process helps improve their digital literacy and ability to communicate effectively with others, which are crucial in this modern era.

Social media also serves as an effective platform for conversation and information sharing. Teenagers can participate in discussion groups on platforms focused on topics they care about, such as academics, arts, and sports, as well as

contemporary social issues like politics (Rheingold, 2020). Actively participating in these forums also helps them develop critical awareness of social issues and provides a platform for voicing their opinions. Social media can also help teens express themselves creatively. They can express their identity and celebrate their uniqueness by sharing photos, videos, and stories with their online friends. This is especially important during adolescent identity development, a crucial stage in the journey to adulthood.

The Negative Influence of Social Media on Teenagers

Social media has many advantages and positive impacts, but excessive and uncontrolled use can have detrimental effects. Social media addiction is one of the most dangerous effects. Social media is highly addictive because of algorithms designed to increase user engagement. Teenagers who are addicted to social media will spend excessive time on it, ultimately neglecting more important offline activities, such as studying, exercising, or interacting directly with friends and family.

Social media addiction can also harm teens' mental health. Excessive social media use has been linked to anxiety, depression, and sleep disturbances in adolescents (Twenge & Campbell, 2018). Teenagers, especially those who often lack self-confidence, will be vulnerable to experiencing significant psychological stress due to continuous exposure to content that is intended to gain attention and appreciation through the use of likes, comments, and shares.

Another serious negative impact of social media use is cyberbullying. Social media provides anonymity and distance, allowing people to engage in bullying behavior without fear of repercussions (Tokunaga, 2010). Teenagers who are victims of cyberbullying can experience several psychological traumas, such as an increased risk of depression, anxiety, and even suicidal thoughts. According to research by Marsinun and Riswanto (2020), cyberbullying negatively impacts adolescents' mental health, with symptoms such as depression, anxiety, sleep disturbances, and decreased academic performance.

Social media use can also lead to deviant behavior in adolescents. Strong peer influence on social media can encourage other adolescents to imitate the negative or risky behavior they see there. Adolescents, who are still in an immature cognitive development stage, are vulnerable to negative influences and lack the ability to evaluate the long-term impact of their behavior.

Furthermore, social media can also contribute to self-confidence and body image issues for teenagers. Unrealistic beauty standards, such as extremely fair skin, a small waist, a thin face, long legs, and so on, can be created by content filled with heavily filtered and edited photos (Grabe et al., 2008). Teenagers, especially girls, who compare themselves to these curated and polished photos may experience feelings of dissatisfaction with their own appearance, which can lead to eating disorders and other health problems.

Method

This paper uses a comprehensive literature review method. This method was chosen because it allows the author to collect and analyze information from various sources relevant to the research topic. Data sources for this study come from

international and national scientific journals, research articles, textbooks, and published research reports.

The data collection process was conducted through searches in leading academic databases, including Google Scholar, ScienceDirect, Elsevier, PsycNet, and Sage Publications, as well as local databases such as those maintained by the Ministry of Education and Culture, and journal websites from various universities. The search was conducted using predetermined keywords, both in English and Indonesian, such as: "social media and adolescent behavior", "social media and adolescent behavior", "cyberbullying and social media", "social media addiction and adolescents", "social media addiction and teenagers", and other relevant keyword combinations. Inclusion criteria in source selection included: (1) research published in the last five to ten years; (2) articles written in English or Indonesian; and (3) research discussing the influence of social media on adolescent behavior and characteristics.

Data analysis was conducted using a thematic approach, where the authors identified key themes emerging from various literature sources. These themes were grouped based on the positive and negative influences of social media on adolescents. Each theme was then analyzed in depth to understand the mechanisms, influencing factors, and implications for adolescents' lives.

Findings and Discussion

Based on the literature review, the authors identified important findings regarding the influence of social media on adolescent behavior and characteristics. These findings demonstrate consistent patterns across studies, despite variations in magnitude and context.

Expanding Social Networks and Global Connections

One of the most significant findings is that social media helps teenagers significantly expand their social networks. According to the literature, teenagers who are active on social media have an average of between 150 and 300 connections, far exceeding Dunbar's cognitive capacity, which suggests that people can maintain approximately 150 social connections (Lindenfors et al., 2021). Social media platforms allow teens to build and maintain relationships with people from diverse cultural and geographic backgrounds.

This global connection also impacts adolescent development. On the one hand, it enables language learning, the development of a global perspective, and cultural exchange. Adolescents can learn about perspectives and ways of life from people around the world. Conversely, too broad a connection can also lead to a lack of depth in relationships with those around them and make it difficult to maintain them.

Impact on Communication Skills

The results of a literature review related to the influence of social media on adolescents' communication skills. According to some literature, social media use can help adolescents express their ideas in writing. Adolescents can learn to write well, become more creative, and can learn to change their way of speaking for different audiences when they create content for social media uploads. This aligns

with digital literacy theory, which emphasizes that active participation in digital media is an important way to learn in the modern era (Jenkins, 2006).

However, literature also indicates that excessive social media use is often associated with a lack of ability for teenagers to communicate directly or personally with those around them. Teenagers who spend too much time communicating digitally through social media are likely to miss out on opportunities to learn important skills in communicating with others directly, such as reading body language, handling conflict directly, and understanding empathy in face-to-face interactions (Turkle, 2011).

Social Media Addiction and Mental Health Impacts

Several studies have shown that social media addiction is a significant problem for adolescents. Social media addiction refers to excessive or uncontrolled social media use that negatively impacts various aspects of life. A study by Twenge and Campbell (2018) found that adolescents who spend more than five hours daily on social media have 71% higher rates of depression and anxiety compared to adolescents who spend only one hour daily.

Social media addiction can be linked to a variety of mental health issues, including sleep disturbances, body dissatisfaction, and low self-esteem. Social media algorithms create a highly addictive environment to increase user engagement and time spent on the platform. Combining reward systems in the form of likes, comments, and shares stimulates the release of dopamine in users' brains. This creates an addictive cycle similar to gambling or other substance use. Furthermore, social media use increases narcissistic behavior among adolescent users (Wibowo & Silaen, 2018).

Cyberbullying and Digital Violence

Cyberbullying has become increasingly prevalent in the social media era. An article by Marsinun and Riswanto (2020) defines cyberbullying as the use of digital technology to engage in repeated intimidating and bullying behavior against an individual or group. According to the article, more than 60 percent of Indonesian adolescents have experienced or witnessed cyberbullying on social media.

Cyberbullying differs from traditional bullying in several ways. First, cyberbullying can occur anytime and anywhere because social media platforms are accessible 24/7. Second, bullying content can be seen by hundreds or thousands of people and remains online indefinitely. Third, some platforms offer anonymity, making it easier for cyberbullies to hide their identities (Siegle, 2010).

Cyberbullying has serious psychological effects on adolescents. A significant relationship between cyberbullying and adolescent anxiety levels was found in research conducted by Baranandita and Asfari (2022). Adolescents who are victims of cyberbullying are also more likely to experience social isolation and depression, even suicide attempts (Baranandita & Asfari, 2022).

Influence on Self-Identity and Self-Confidence

Social media plays a significant role in shaping adolescents' complex identities. These platforms also allow teens to explore various aspects of their identities and gain feedback from their peer groups (Bobkowski et al., 2016).

Teenagers can try on different personas, styles, and principles while remaining anonymous.

On the other hand, excessive use of social media can lead to false self-presentation and comparison traps. The social comparison theory created by Festinger (1954) states that people will tend to compare themselves with others to evaluate themselves (Festinger, 1954). Teenagers do this on social media by comparing themselves to content that has been filtered and curated by others, which often only shows the best parts of their lives (Vogel et al., 2014).

According to research conducted by Grabe et al. (2008), there is a significant link between social media use and body dissatisfaction among adolescents, especially girls. If they see edited and filtered images or photos on social media, they will naturally develop unrealistic beauty standards and become dissatisfied with their own appearance. This can develop into more serious health problems, such as eating disorders and body dysmorphic disorder (Grabe et al., 2008).

Erikson's theory emphasizes that adolescence is a critical phase in the formation of personality, values, and social skills. During this period, individuals explore identity, develop self-concept, and face the identity crisis. The developmental outcomes related to self-identity, social networking, and mental health found in the literature review are directly relevant to this stage.

Adolescence is conceptualized by Erikson as a psychosocial moratorium or a sanctioned intermediary period during which society allows the individual time to experiment with various roles and achieve a synthesis of previous identifications. Social media platforms allow teenagers to explore various aspects of their identities and gain feedback from their peer groups. This environment provides opportunities for self-expression, which is crucial during adolescent identity development. The expansion of social networks to diverse geographic and cultural backgrounds allows adolescents to build meaningful relationships with people sharing similar interests and values, providing broader cultural input necessary for identity construction. Excessive social media use complicates this process, leading to false self-presentation and comparison traps. The concept of ego identity requires a sense of self that is temporally continuous and possesses socially validated defining characteristics. However, when teenagers are continuously exposed to filtered and curated content, they rely on Festinger's Social Comparison Theory, comparing themselves to unrealistic standards. This results in dissatisfaction with their own appearance and can lead to serious health issues like eating disorders. This inability to reconcile internal self-perception with external, curated social standards contributes to identity confusion, which manifests as contradictory self-images or a loss of center.

The findings linking excessive social media use to high rates of depression, anxiety, and sleep disturbances indicate significant psychological stress. Erikson describes the identity crisis as a turning point that can result in prolonged identity confusion. The mental health issues observed suggest that for many adolescents, social media use contributes to an aggravated identity crisis. This is particularly true for those who often lack self-confidence and are highly vulnerable to the psychological stress derived from seeking digital attention and appreciation. The lack of depth in relationships resulting from overly broad global connections may also hinder the establishment of stable, supportive relationships necessary to validate a positive ego identity (Côté & Levine, 1987).

Bandura's theories emphasize that learning occurs via observation, imitation, and modeling in a social context. SCLT focuses on how human thought processes are central to understanding behavior, involving a reciprocal interaction between personal factors, behavior, and the environment (triadic reciprocity). The finding that strong peer influence on social media can encourage adolescents to imitate negative or risky behavior is a direct application of Bandura's theories. Social media platforms provide symbolic models, displaying behaviors through real or fictional characters, videos, or posts. Aggression and moral behavior can be learned through such models. Because adolescents are still in an immature cognitive development stage, they are particularly vulnerable to these negative influences and lack the ability to evaluate the long-term impact of the modeled behavior.

Cyberbullying is characterized by repeated intimidating behavior using digital technology. This behavior is learned and sustained partly through the observation of consequences. Social media facilitates bullying due to anonymity and distance. This aligns with the concepts of response facilitation effect (increased frequency of learned behavior after a model is reinforced) or, inversely, the response inhibition effect (decreased frequency after observing a punished model). When users observe bullying without immediate negative repercussions, the behavior is more likely to be imitated.

The highly addictive nature of social media is linked to algorithms designed to maximize engagement and time spent on the platform. This is explained by Bandura's concept of intrinsic reinforcement, which refers to internal rewards such as pride, satisfaction, and a sense of accomplishment. The reward systems on social media (likes, comments, and shares) stimulate the release of dopamine in the brain, creating an addictive cycle. This external reinforcement (likes/comments) leads to internal satisfaction (intrinsic reinforcement), motivating users to continuously engage in the behavior (posting/sharing). Furthermore, reinforcement and punishment are critical components of motivation in modeling. The desire to receive likes and affirmation reinforces the presentation of a "best parts only" curated self, which can contribute to the noted increase in narcissistic behavior among adolescent users.

If the developmental journey of a teenager is like building a house (Ego Identity Formation), social media acts as a vast, unregulated public market (psychosocial moratorium) where the teenager gathers materials (role experimentation). Bandura's theory dictates that if the teenager sees others rewarded (intrinsic reinforcement/likes) for acquiring fragile or damaging materials (deviant behavior/false self-presentation), they will be motivated to choose those too, potentially leading to a flawed structure that cannot withstand the pressures of adulthood or Identity Confusion (Nabavi & Bijandi, 2012).

Conclusion

Based on the literature review, it can be concluded that social media influences adolescent behavior and traits in a complex and bidirectional manner. Social media has many benefits, such as expanding social networks, helping people communicate better in certain situations, and providing opportunities for self-expression and discussion on important issues. Social media provides adolescents with the opportunity to access important information, strengthen their identity, and connect with communities worldwide.

However, the negative impacts of social media cannot be ignored. Significant negative impacts experienced by adolescents include social media addiction, cyberbullying, mental health issues, and body dissatisfaction. Excessive social media use can reduce important face-to-face interactions, increase levels of anxiety and depression, and create an environment prone to negative behavior.

The impact of social media on adolescents largely depends on how they use it. Conscious use can maximize benefits while minimizing risks, while excessive and uncontrolled use can have significant negative effects. Therefore, ensuring that adolescents can use social media safely, healthily, and beneficially for their development requires collaboration between various parties, including parents, educators, policymakers, and social media platform providers.

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CLUSTERING SENIOR HIGH SCHOOL STUDENTS' NUMERACY SCORE IN JAVA USING THE K-MEANS ALGORITHM

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Received: 2 November 2025; Accepted: 25 November 2025

Abstract

Numeracy skill is a key ability that supports critical thinking and is assessed in Indonesia through the Minimum Competency Assessment. This study aims to (1) analyze high school students' numeracy skills in Java based on four numeracy domains and three cognitive levels; and (2) cluster students' numeracy skills using the K-Means algorithm with the Davies-Bouldin Index (DBI) as the evaluation metric. The data were obtained from the education data portal for the year 2021–2023. The process went through several stages: data cleaning, normalization, feature selection, clustering, and validation using the Davies–Bouldin Index (DBI). The results indicate a steady improvement in students' numeracy performance, with average scores increasing from 51.18 in 2021, 54.08 in 2022, and 59.19 in 2023. The clustering process resulted in four clusters in 2021 and 2022 and two clusters in 2023. The clustering results revealed four distinct groups in 2021 and 2022, representing high, moderate, fluctuating, and low numeracy performance across regions. In 2023, these merged into two clusters, indicating reduced disparity and greater uniformity in students' numeracy achievement across Java. Furthermore, it provides insights for educators and policymakers to design targeted interventions to improve students' numeracy skills and reduce learning gaps across regions.

Keywords: clustering, Davies-Bouldin Index, K-Means algorithm, national assessment, numeracy

Introduction

Numeracy is a crucial skill for every individual. In the 21st century, where technological advancements and digitalization are so prevalent, this ability is crucial for supporting critical thinking skills, enabling better decision-making, and contributing to individual well-being (Fajriyah, 2022; Nurfadillah et al., 2024). Numeracy itself can be defined as the ability to use basic mathematics, such as numbers and symbols, to solve real-world problems and analyze information presented in graphs, tables, and other forms (Mariamah et al., 2021). This demonstrates that numeracy is not limited to academic contexts but also contributes significantly to everyday life.

In Indonesia, numeracy is one of the cognitive abilities measured through the Minimum Competency Assessment (AKM) in the National Assessment (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia, 2021). This assessment is designed to measure students' competency levels, which can be used to design improvements to the learning process and improve student



learning outcomes. There are four numeracy competency domains used in the AKM: Number, Geometry and Measurement, Algebra, and Data and Uncertainty. Numeracy is measured across three cognitive levels: Knowing, Applying, and Reasoning.

The results of the 2021-2023 National Assessment (AN) for high school students indicate that student competency achievement is still suboptimal and tends to vary. This aligns with the statement by Sukaryo and Sari (2024), who stated that the numeracy skills of high school students in Indonesia are still suboptimal and need to be improved. Yet, improving numeracy skills is a crucial factor in developing high-quality and competitive human resources (Anderha & Maskar, 2021). This situation certainly poses a challenge for Indonesia in improving and equitable education, including in numeracy.

With the advancement of technology, educational data, such as National Assessment results, can be further processed and analyzed to help address various challenges in education. One possible approach is data mining, which is the process of extracting valuable knowledge from data using mathematical, statistical, and artificial intelligence techniques (Kononeko & Kukar, in Muttaqin et al., 2023). Data mining can facilitate data collection, processing, and analysis to support better decision-making in education.

The data mining method used in this study is clustering with the K-Means algorithm. Clustering is a method of grouping objects based on certain conditions, where objects within a group (cluster) have a high degree of similarity to each other and a high degree of dissimilarity to objects in other clusters (Farissa et al., 2021). With this method, national assessment results are used to group regions with similar numeracy ability characteristics, thus enabling them to develop more targeted learning improvement strategies.

The K-Means clustering algorithm is one of the oldest, most powerful, and most popular data mining techniques used in research because of its ease of implementation and high processing speed (Ahmed et al., 2020; Faizah et al., 2020). It has a high level of accuracy regarding object size, allowing it to efficiently handle large datasets (Rosida & Wijaya, 2023). The K-Means algorithm has been widely used in educational research, such as clustering national exam results (Suputra et al., 2021), grouping high-achieving students (Rahayu et al., 2024), and identifying scholarship recipients (Harahap & Rambe, 2021).

However, the quality of K-Means clustering results is highly dependent on the initial selection of cluster centers, so it is very important to determine the initial cluster centers correctly (Yu et al., in Setyaningtyas et al., 2022). One method that can be used to evaluate clustering results is the Davies-Bouldin Index (DBI). The results of the DBI calculation can be used as a reference in determining the optimal number of clusters, which is achieved when the model produces the smallest DBI value (Ashari et al., 2022).

This research focuses on the island of Java, which is the center of economic, political, and other development activities in Indonesia. Java also dominates Indonesia's population, accounting for 56.1% (Purnamasari, 2024). Furthermore, as a major center of education, Java plays a crucial role in the advancement of education in Indonesia, particularly with its easy access, comprehensive facilities, and high standards (Putri et al., 2023).

Based on this background, this study focuses on Java Island as a region with a strategic role in educational development in Indonesia. Java Island has a relatively advanced educational infrastructure and the largest population, but still shows variations in numeracy achievement between provinces. Therefore, this study aims to (1) analyze the numeracy abilities of senior high school students in Java Island based on four numeracy domains and three cognitive levels, and (2) group students' numeracy abilities using the K-Means algorithm with the Davies–Bouldin Index (DBI) as an evaluation metric.

Method

This study uses secondary data in the form of national assessment results taken from the education data portal at <https://data.kemendikdasmen.go.id/>. The data used are high school students' numeracy scores from the 2021-2023 National Assessment, covering the following variables.

Table 1. Description of Research Variables

Variable	Description
kd_siswa_an	Student code
kd-kokab	City/regency code
provinsi	Province
NUM	Numeracy score
NUM_ALJ	Score in Algebra domain
NUM_GEO	Score in Geometry domain
NUM_BIL	Score in Number domain
NUM_DAT	Score in Data and Uncertainty domain
NUM_L1	Score in level 1 (Knowing)
NUM_L2	Score in level 2 (Applying)
NUM_L3	Score in level 3 (Reasoning)

This research focuses on the island of Java, which includes the provinces of Banten, Jakarta, West Java, Central Java, Yogyakarta, and East Java. Data were collected for 10,141 cases in 2021, 10,264 cases in 2022, and 10,266 cases in 2023. Of the 119 regencies/cities in Java, available data only cover 82. Data processing was performed using Python.

Table 2. Distribution of Students and Schools by Province in Java

Province	Number of Students			Number of Schools		
	2021	2022	2023	2021	2022	2023
Banten	1979	2009	2035	57	56	56
West Java	1773	1765	1828	48	47	47
DKI Jakarta	1222	1291	1282	35	34	34
Central Java	1505	1545	1566	40	40	40
DIY	1471	1518	1514	42	41	41
East Jawa	2040	2004	1963	59	57	58

Data analysis in this study was conducted through five main stages: (1) data cleaning, (2) standardization, (3) feature selection, (4) clustering, and (5) validation. These stages were adapted from the general procedure for data mining analysis using the K-Means algorithm (Stiadi & Sundani, 2021).

1. *Data Cleaning*

At this stage, data cleaning was performed, including handling missing values, duplicate data, and outliers. Missing values were removed without input to maintain the authenticity of the data used in the analysis. Meanwhile, no duplicate data was found in 2021, 2022, or 2023. However, outliers were not removed because they could provide important insights into the actual situation. After data cleaning, clean data were obtained for 9.990 in 2021, 10.132 in 2022, and 10.188 in 2023. The number of participating students and schools is presented in Table 2.

2. *Standardization*

At this stage, data standardization is carried out on the 'NUM' variable, which will be used as a reference for the clustering process.

3. *Feature Selection*

In the feature selection stage, variables used in the clustering process are selected based on their relevance to students' numeracy abilities. The variables used include numeracy domain scores (NUM, NUM_ALJ, NUM_GEO, NUM_BIL, NUM_DAT) and cognitive levels (NUM_L1, NUM_L2, NUM_L3). This feature selection aims to obtain the most informative data representation and avoid redundancy between variables.

4. *Clustering*

The clustering process is performed using the K-Means algorithm. This algorithm works by minimizing the sum of the distances in each cluster using the Euclidean distance measure, performed iteratively (Aditya et al., 2020). The steps in this algorithm are as follows (Maori & Evanita, 2023).

- 1) Determine the number of clusters (k value) to be formed.
- 2) Randomly determine the initial center points (k centroids) for each cluster.
- 3) Calculate the distance between each data point and each centroid using the following formula for the distance between two objects (Euclidean distance).

$$D_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + \dots (n_i - n_j)^2}$$

with:

D_{ij} = distance between objects i dan centroid j

x_i = x coordinate of the object

x_j = x coordinate of center (centroid)

y_i = y coordinate of the object

y_j = y coordinate of center (centroid)

- 4) Group the data into clusters based on the closest distance between the data and the centroid.
- 5) Determine the new centroid by calculating the average value of all data in each cluster.
- 6) Repeat steps 3-5 until you find a suitable cluster that meets certain conditions.

5. Validation

The best number of clusters (k value) is determined based on the Davies-Bouldin Index (DBI) calculation. DBI evaluates clusters based on the proximity between cluster members (intra-cluster distance) and the separation between clusters (inter-cluster distance). The DBI calculation can be performed using the following formula (Hassan et al., 2021),

$$DBI = \frac{1}{k} \sum_{i=1}^k \max_{i \neq j} R_{i,j}$$

where

$$R_{i,j} = \frac{WSS_i + WSS_j}{BSS_{i,j}}$$

$$WSS_i = \frac{1}{n_i} \sum_{i=1}^{n_i} d(x_i - c_i)$$

$$BSS_{i,j} = d(c_i, c_j)$$

where $d(x, y)$ is the distance between two points, WSS_i is the average intra-cluster distance between data (x_i) and the centroid (c_i) of the cluster, $BSS_{i,j}$ is the inter-cluster distance between the centroids of cluster i (c_i) and cluster j (c_j), and $R_{i,j}$ is the ratio between the inter-cluster and intra-cluster distances. The best k value is determined from the smallest DBI value, namely by striving for maximum inter-cluster distance and minimum intra-cluster distance (Jollyta et al., 2023). A large inter-cluster value indicates bigger differences between clusters, or in other words, smaller similarities between clusters, while a small intra-cluster value indicates better similarities within a cluster (Gustriansyah et al., 2020).

Findings and Discussion

Descriptive Analysis

Based on Table 3 and Figure 1, it can be seen that there is an increase in high school students' numeracy scores from year to year. In 2021, the average numeracy score was recorded at 51.18, then increased to 54.08 in 2022 and reached 59.19 in 2023.

Table 3. Average Numeracy Score of Senior High School Students in Java Based on Domains and Cognitive Levels (2021-2023)

Observed Aspects	2021	2022	2023
Numeracy	51.18	54.08	59.19
Aljabar Domain	49.89	53.50	59.14
Geometry Domain	49.66	53.09	57.34
Number Domain	51.38	52.75	58.55
Data and Uncertainty Domain	51.54	52.27	60.44

Knowing	49.79	52.73	54.39
Applying	51.00	55.13	59.57
Reasoning	51.94	52.45	58.54

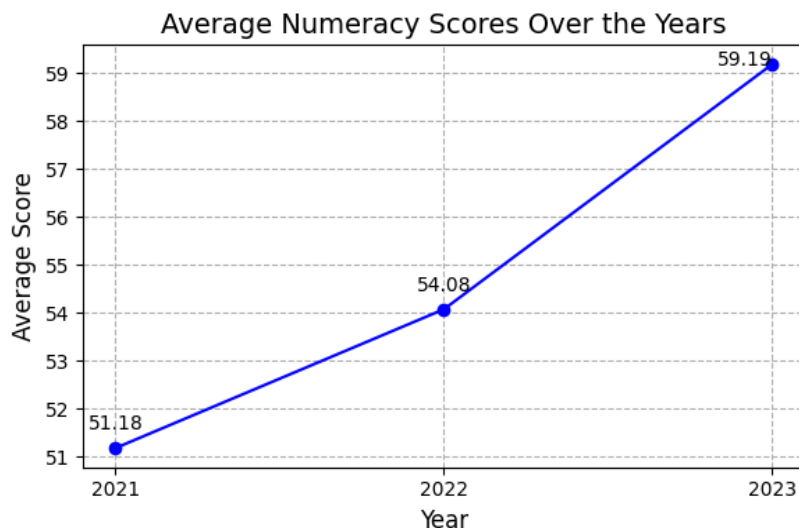


Figure 1. Average Numeracy Scores Over the Years

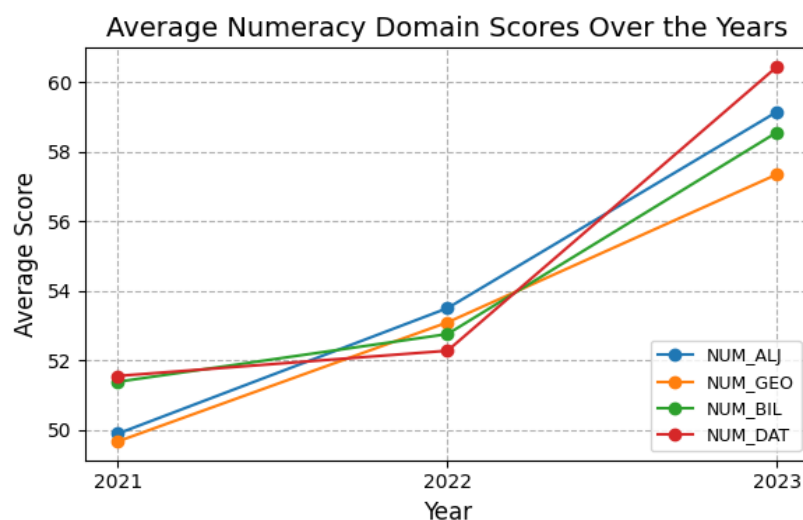


Figure 2. Average Numeracy Domain Scores Over the Years

Based on the numeracy domain, as shown in Figure 2, it can be seen that all domains have increased each year. The most significant improvement occurred in the Data and Uncertainty domain, followed by the Algebra domain, indicating growing student abilities in interpreting data, understanding probability, and performing symbolic reasoning. The results of this study are in line with the findings of Nugraha and Rudhito (2025), who also noted a significant increase in the Data and Uncertainty domain.

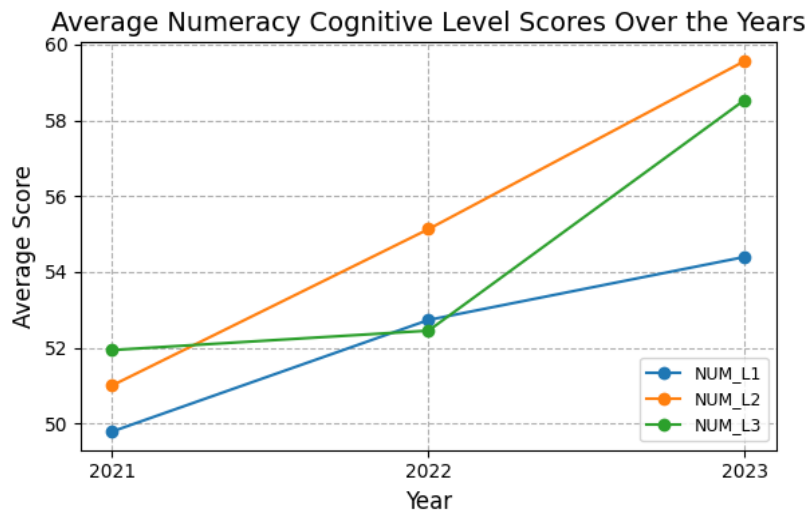


Figure 3. Average Numeracy Cognitive Level Scores Over the Years

Based on cognitive levels, as shown in Figure 3, the applying competency (L2) experienced fairly steady improvement and became the highest competency in 2022 and 2023. The reasoning competency (L3) showed the most significant improvement in 2023, compared to other competencies. Meanwhile, the knowing competency (L1), the most basic competency, tended to be the lowest-performing, although it also experienced improvement from year to year. This may indicate a lack of students' fundamental understanding of basic numeracy concepts. However, it also indicates that the learning process in schools is beginning to emphasize higher-order thinking skills (HOTS), rather than simply procedural and memorizing material. This is a positive sign because it indicates an improvement in the quality of students' thinking abilities.

The three graphs in Figures 4-6 show variations in average numeracy scores across regencies/cities on Java Island during the 2021-2023 period. The dashed red line in each graph represents the average numeracy score for Java Island. It can be seen that the majority of regions have average scores close to the overall average for Java Island. However, several regions remain extremely prominent, either significantly above or significantly below the average. This situation illustrates the persistence of gaps in numeracy learning between regions.

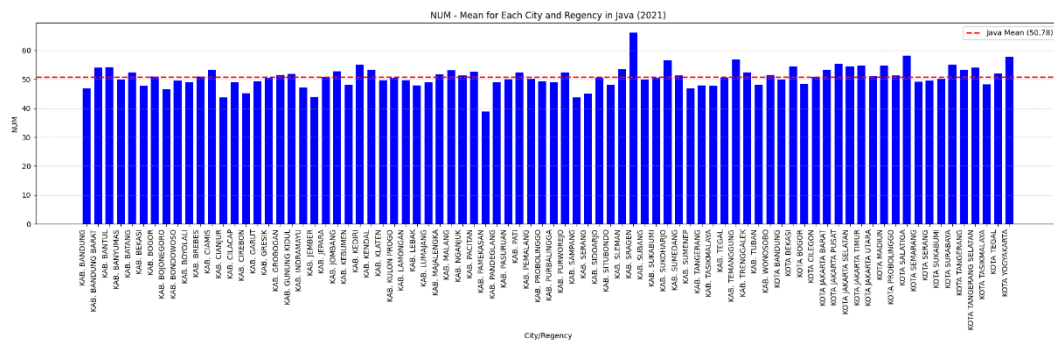


Figure 4. Average NUM Score for Each City and Regency in Java (2021)

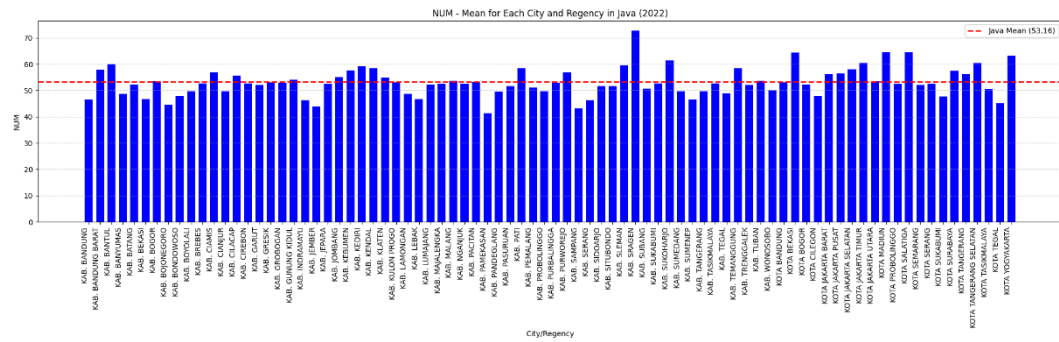


Figure 5. Average NUM Score for Each City and Regency in Java (2022)

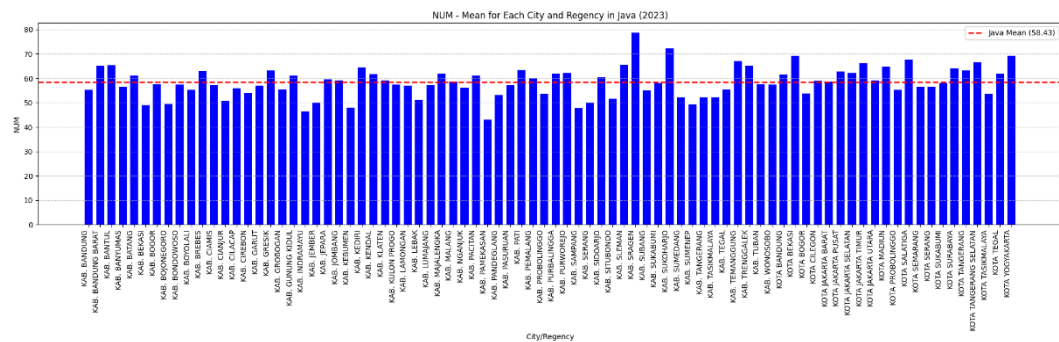


Figure 6. Average NUM Score for Each City and Regency in Java (2023)

The data shows that Sragen Regency consistently ranks among the regions with the highest average numeracy scores in Java. When viewed provincially, as shown in Table 4, DKI Jakarta and Yogyakarta consistently achieve higher average numeracy scores than other provinces on Java, while Banten consistently ranks last. Overall, there is a trend of increasing numeracy skills across all provinces, indicating an improvement in the quality of learning from year to year. However, the gap in numeracy scores has also widened each year, from 4.52 points in 2021 to 6.94 in 2022 and to 8.23 in 2023.

Table 4. Average NUM Score for Each Province in Java

2021		2022		2023	
No	Province	Score	Province	Score	Province
1	DKI Jakarta	53.89	DIY	58.50	DIY
2	DIY	53.86	DKI Jakarta	57.64	DKI Jakarta
3	Central Java	52.03	Central Java	54.47	Central Java
4	East Java	50.24	West Java	52.38	East Java
5	West Java	49.47	East Java	52.14	West Java
6	Banten	49.37	Banten	51.56	Banten

Overall, numeracy scores across all aspects increased during the 2021-2023 period, indicating a positive trend in the learning process year after year. However, a significant gap in numeracy scores between regions still occurs. This disparity can be caused by several factors, such as differences in teacher and school quality, the availability of learning facilities, accessibility to learning resources, and technical

factors like variations in the size and composition of samples from each region. Therefore, sustained and targeted efforts are essential to reduce disparities between regions and improve the equity of education quality.

Clustering

Table 5. DBI Score 2021

Number of Clusters	DBI Score
2	0.715770
3	0.711491
4	0.543961
5	0.574736
6	0.639801
7	0.567050
8	0.589554
9	0.657457
10	0.713217

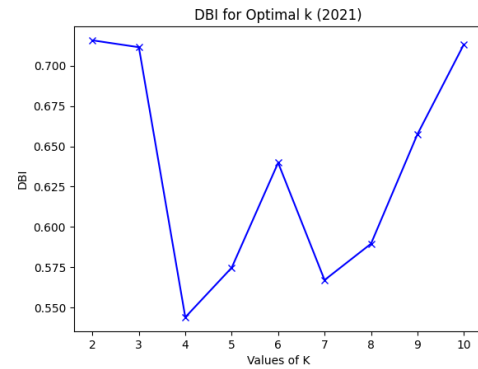


Figure 7. DBI Score 2021

Table 6. DBI Score 2022

Number of Clusters	DBI Score
2	0.616860
3	0.579215
4	0.469287
5	0.560565
6	0.589835
7	0.669399
8	0.693224
9	0.729867
10	0.703823

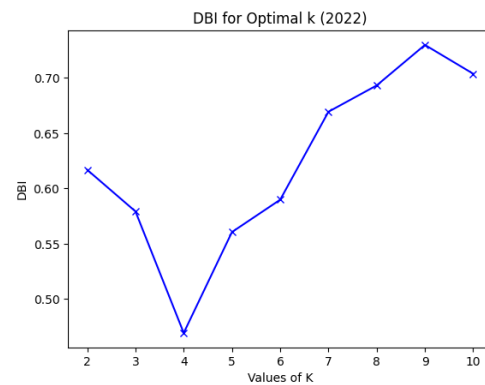


Figure 8. DBI Score 2022

Table 7. DBI Score 2023

Number of Clusters	DBI Score
2	0.739795
3	0.767287
4	0.837971
5	0.866033
6	0.761890
7	0.739853
8	0.761530
9	0.802851
10	0.894526

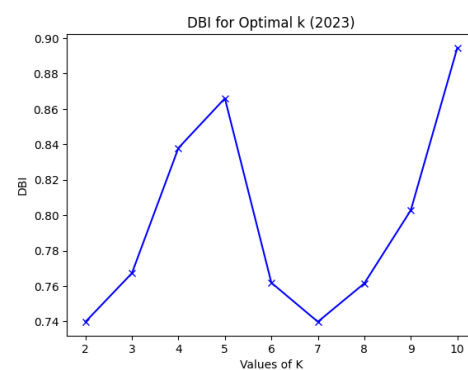


Figure 9. DBI Score 2023

Based on the DBI principle in determining the optimal number of clusters, namely the cluster with the lowest DBI result, the number of clusters is set at four clusters for 2021 and 2022, and two clusters in 2023. The decrease in the number of clusters from four to two in 2023 may indicate an increasing tendency for homogeneity or uniformity of numeracy scores between regencies/cities on the

island of Java, or in other words, the variation in scores between regencies/cities tends to decrease.

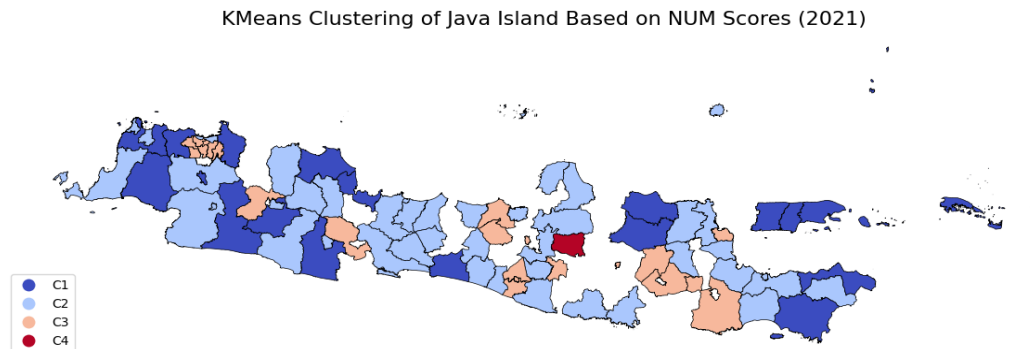


Figure 10. K-Means Clustering of Java Island Based on NUM Scores (2021)

Table 8. K-Means Clustering of Java Island Based on NUM Scores (2021)

Variable	Cluster			
	C1	C2	C3	C4
Cluster Members	18	42	21	1
Mean NUM	46.16	50.51	54.57	66.15
Mean NUM_ALJ	44.58	49.39	53.62	63.16
Mean NUM_GEO	45.88	49.46	52.01	62.81
Mean NUM_BIL	46.05	50.70	54.99	66.98
Mean NUM_DAT	46.45	51.06	55.00	66.96
Mean NUM_L1	44.27	49.14	53.40	66.54
Mean NUM_L2	46.28	50.30	54.40	65.76
Mean NUM_L3	47.50	51.60	54.92	65.09

In 2021, the majority of regencies/cities in Java were grouped into cluster C2. Cluster C4 has the highest average score and only has one member, Sragen Regency. Meanwhile, cluster C1 has the lowest average score, dominated by regions from West Java and East Java Provinces. Interestingly, no regions from DKI Jakarta or Yogyakarta are included in this cluster.

Compared to the overall average for Java, clusters C1 and C2 have average scores below the overall average across all domains and cognitive levels, while clusters C3 and C4 have average scores above the overall average across all domains and cognitive levels. Unfortunately, the majority of regions are still included in clusters C1 and C2, indicating the persistently low numeracy skills in a significant number of regencies/cities in Java.

Of the four numeracy domains, the Data and Uncertainty domain had the highest average scores in each cluster. This is consistent with the overall data for Java, where this domain also had the highest scores in 2021. Meanwhile, clusters C1 and C2 had the lowest scores in the Algebra domain, while clusters C3 and C4

had the lowest scores in the Geometry domain. This indicates that the ability to understand data and uncertainty is relatively strong, while algebra remains a weakness in the lower clusters, and geometry is a weakness in the higher clusters.

From the cognitive level, knowing competency (L1) is the lowest in clusters C1, C2, and C3, while reasoning competency (L3) is the highest in these clusters. This aligns with the overall average results for Java, where reasoning competency (L3) received the highest average and knowing competency (L1) received the lowest average. However, this result is reversed in cluster C4, where knowing competency (L1) received the highest score, and reasoning competency (L3) received the lowest score. This may indicate that high numeracy skills are not only caused by critical thinking skills, but also by strong mastery of basic concepts.

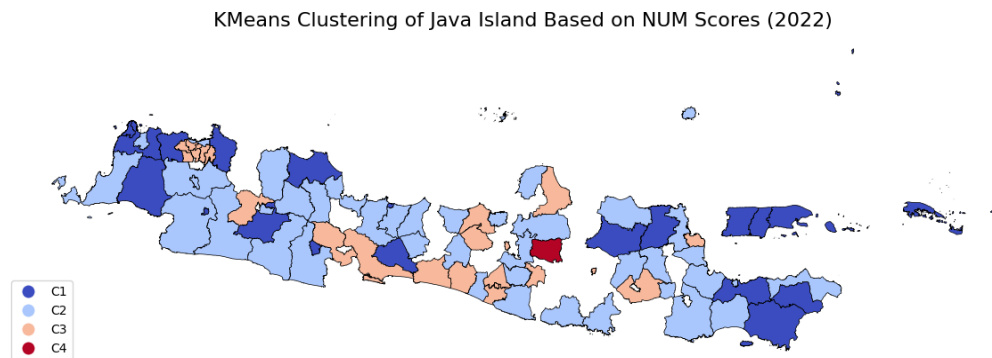


Figure 11. K-Means Clustering of Java Island Based on NUM Scores (2022)

Table 9. K-Means Clustering of Java Island Based on NUM Scores (2022)

Variable	Cluster			
	C1	C2	C3	C4
Cluster Members	19	39	23	1
Mean NUM	46.71	52.22	59.22	72.80
Mean NUM_ALJ	45.80	52.01	58.75	70.08
Mean NUM_GEO	45.90	51.72	58.12	70.41
Mean NUM_BIL	46.24	51.27	57.49	70.44
Mean NUM_DAT	45.06	50.67	57.49	69.59
Mean NUM_L1	45.05	50.92	58.58	73.85
Mean NUM_L2	48.30	53.76	59.670	68.57
Mean NUM_L3	45.69	51.05	57.13	67.97

The clustering pattern in 2022 was similar to the previous year, with Cluster C2 remaining the most numerous, and Sragen Regency remaining the sole member of Cluster C4. However, positive shifts were observed in several regions, such as Bogor City and Situbondo Regency, which previously ranked in the lowest cluster (C1), moving up to Cluster C2, and Kebumen Regency, which rose from cluster C1 to Cluster C3. Conversely, several regions experienced a decline from Cluster C2 to Cluster C1.

The numeracy domain showed significant changes compared to the previous year. The Data and Uncertainty domain, which had the highest scores in each cluster in the previous year, was the lowest this year. Conversely, the Algebra domain, which in the previous year had the lowest scores in clusters C1 and C2, showed significant improvement this year and became the highest-scoring domain in clusters C2 and C3. Meanwhile, the Geometry domain held the highest position in cluster C1, and the Number domain held the highest position in cluster C4. This shift indicates that the improvement in numeracy skills this year was more evenly distributed across various domains compared to the previous year, which was more concentrated in a single domain.

In terms of cognitive level, cluster C4 exhibited similar characteristics as the previous year, with the knowing competency (L1) having the highest score and the reasoning competency (L3) the lowest. Meanwhile, in clusters C1 and C2, the knowing competency (L1) remained the lowest-scoring competency, while the reasoning competency (L3) was the lowest in cluster C3. Furthermore, the applying competency (L2) was the highest-scoring competency in clusters C1, C2, and C3, indicating an emphasis on applying competency this year.

KMeans Clustering of Java Island Based on NUM Scores (2023)

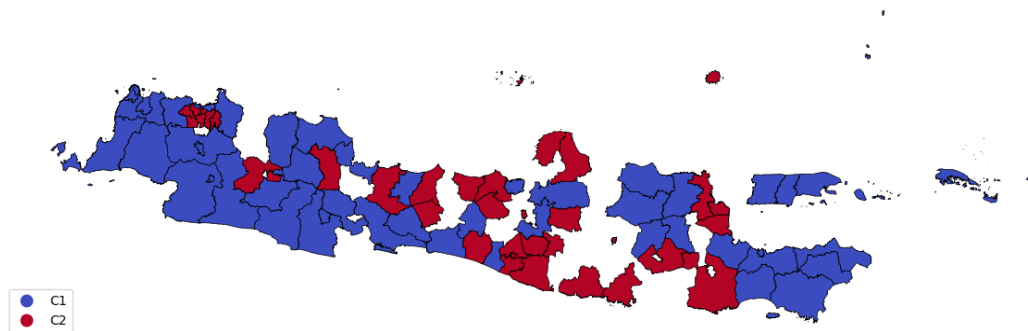


Figure 12. K-Means Clustering of Java Island Based on NUM Scores (2023)

Table 10. K-Means Clustering of Java Island Based on NUM Scores (2023)

Variable	Cluster	
	C1	C2
Cluster Members	46	36
Mean NUM	54.16	63.89
Mean NUM_ALJ	53.83	64.53
Mean NUM_GEO	54.39	59.91
Mean NUM_BIL	53.20	63.43
Mean NUM_DAT	54.48	65.35
Mean NUM_L1	47.72	60.01
Mean NUM_L2	54.12	64.28
Mean NUM_L3	54.10	63.16

In 2023, the clustering results were quite different from previous years, with the number of clusters decreasing from four to two. Cluster C1 had a lower average score and a larger number of members than cluster C2. Geographically, cluster C2 is more concentrated in the central region of Java, with most of its members coming from Central Java Province. Meanwhile, cluster C1 appears more dispersed, with the majority of its members coming from West Java and East Java Provinces. Furthermore, the majority of areas in the provinces of DKI Jakarta, Yogyakarta, and Central Java are included in cluster C2. In fact, DKI Jakarta and Yogyakarta have only one regency/city included in cluster C1: North Jakarta and Kulon Progo Regency.

In terms of numeracy, the Data and Uncertainty domain has improved again and become the domain with the highest scores. Meanwhile, cluster C1 has the lowest score in the Number domain, while cluster C2 has the lowest score in the Geometry domain. This indicates that the Data and Uncertainty domain is the most mastered numeracy skill, while number skills remain a weakness in the lower cluster, and geometry is a weakness in the higher cluster. Meanwhile, when viewed from the cognitive level, this year, all clusters appear to share similar characteristics, with knowing competency (L1) being the lowest competency and applying competency (L2) being the highest.

Overall, the 2023 clustering results show a trend toward more equitable numeracy skills across regions on Java compared to previous years, although disparities remain. Sragen Regency consistently ranks among the clusters with the highest average scores, followed by areas in the Yogyakarta and DKI Jakarta Provinces. Conversely, several regions in Banten, West Java, and East Java provinces consistently rank among the lowest clusters. This pattern indicates that despite improvements and some level of equitable distribution, disparities in numeracy skills persist across regions. In addition, the fact that the majority of regions are still included in the cluster with a low average score shows that improving numeracy skills is still a big challenge, especially for regions that are consistently in the lower cluster.

The clustering results from 2021 to 2023 show an important pattern in the distribution of numeracy skills across Java Island. Although the decrease in the optimal number of clusters may suggest an increase in homogeneity, the reality is that a gap still exists, and the majority of regions remain within the low-performing clusters. This highlights the urge for more targeted learning interventions, considering that not all regions can be treated equally. Furthermore, these findings offer valuable insight for policymakers to identify the specific needs of each region, particularly those consistently grouped in the lower clusters.

Conclusion

The results of the study indicate that the numeracy skills of high school students in Java have increased from year to year, both overall and in each domain and cognitive level. Variations in the pattern of abilities in each domain tend to fluctuate from year to year, while the cognitive level shows a more stable pattern, where the competence of knowing tends to have a lower score than the competence of applying and reasoning. Based on the results of clustering using the K-Means algorithm with Davies-Bouldin Index (DBI) evaluation, the optimal number of clusters formed is four clusters for 2021 and 2022, and two clusters for 2023. This

decrease in the number of clusters may indicate an increasing trend of increasing equality of numeracy skills between regions in Java. However, the fact that each year the majority of regions are still included in the cluster with low scores, and the disparities and gaps that still occur between regions indicate the importance of efforts to improve numeracy skills and educational equality comprehensively and sustainably, especially for regions that are consistently in the cluster with low scores.

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DESIGNING A HUMAN-CENTERED FRAMEWORK FOR PRESERVICE MATHEMATICS PRIMARY SCHOOL TEACHERS: INTEGRATING COMPUTATIONAL THINKING, REFLECTIVE PEDAGOGY, AND ETHNOMATHEMATICS

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Received: 31 October 2025; Accepted: 28 November 2025

Abstract

This paper develops a human-centred curriculum framework for preservice primary school teachers that integrates computational thinking, reflective pedagogy, and ethnomathematics. Applying a Conceptual Systematic Review (CSR) approach, the study synthesises conceptual and empirical literature from 2010 to 2025 to clarify each domain and map intersections relevant to teacher preparation. The framework positions computational thinking as a pedagogical tool for structured problem solving, reflective pedagogy as the ethical and metacognitive anchor, and ethnomathematics as the cultural and ecological grounding. Anticipated outcomes include enhanced teacher readiness for technology-rich classrooms, strengthened culturally responsive practice, and improved capacity for ethical decision-making. The paper concludes with implications for course design, program assessment, and future empirical validation.

Keywords: computational thinking, ethnomathematics, human-centred curriculum, preservice teacher education, reflective pedagogy

Introduction

The digital era demands that mathematics teachers develop comprehensive competencies beyond traditional content knowledge. In the evolution of mathematics education, preservice teacher preparation must respond to increasing demands for digital competence, reflective awareness, and cultural sensitivity. The 21st century has profoundly reshaped mathematics education through globalization, technological innovation, and cultural diversity. Teachers today must navigate not only mathematical content but also ethical, reflective, and cultural complexities (Angeli et al., 2016; Noddings, 2007). Consequently, teacher education must evolve from procedural instruction to human-centred, critical, and creative pedagogies that balance cognition with empathy (Korthagen & Vasalos, 2005; Skovsmose, 2011).

The 21st century has profoundly reshaped mathematics education through globalization, technological innovation, and cultural diversity. Teachers today must navigate not only mathematical content but also ethical, reflective, and cultural complexities (Angeli et al., 2016; Noddings, 2007). Consequently, teacher education must evolve from procedural instruction to human-centered, critical, and creative pedagogies that balance cognition with empathy (Korthagen & Vasalos, 2005; Skovsmose, 2011).



A human-centred mathematics curriculum prioritizes meaning, identity, and social responsibility in teaching (Freire, 1996; Noddings, 2007). It frames mathematics not merely as abstract reasoning but as a human activity rooted in culture, ethics, and collaboration (Boaler, 2016; Rosa & Orey, 2011). Within this view, computational thinking (CT), reflective pedagogy (RP), and ethnomathematics (EM) offer complementary pathways for empowering preservice teachers as reflective, culturally responsive, and technologically competent educators.

Recent research emphasizes that integrating CT fosters deeper problem-solving and modelling skills (Grover & Pea, 2023; Weintrop et al., 2016). Reflective pedagogy enables preservice teachers to examine their beliefs, practices, and classroom ethics (Larrivee, 2000; Schön, 1983), while ethnomathematics situates mathematics in cultural contexts, enhancing inclusion and equity (D'Ambrosio, 2006; Rosa & Orey, 2011). The convergence of these domains supports UNESCO's (2021) vision for "education that empowers learners to shape peaceful, sustainable, and just futures."

Despite these advancements, integration of CT, RP, and EM in mathematics teacher education remains fragmented. CT is often isolated as a technical skill detached from culture or ethics (Sengupta et al., 2018; Wing, 2017). RP is practised as personal reflection but lacks connection to digital pedagogy (Dewey, 2006; Schön, 1983). EM highlights cultural relevance yet rarely intersects with computational or reflective learning (Vithal & Skovsmose, 1997). This fragmentation limits preservice teachers' ability to design lessons that are logically sound, ethically informed, and culturally meaningful.

To address these gaps, this study explicitly advances beyond adjacent frameworks such as TPACK, TPACK-CT, and critical mathematics education by integrating cognitive (CT), ethical-reflective (RP), and cultural (EM) dimensions into one unified, human-centred curriculum model. This is important because current teacher education frameworks rarely articulate how CT can be taught ethically, how reflection can be evidence-based rather than emotional, or how cultural knowledge can guide computational modelling and technological decision-making.

The purpose of this study is to design a Human-Centred Curriculum Framework (HCCF) for preservice primary mathematics teachers by synthesising the theoretical and practical intersections of CT, RP, and EM. Specifically, the objectives are to: (1) analyse conceptual and empirical literature on CT, RP, and EM in mathematics education, (2) identify intersections and complementarities among these domains, (3) develop a curriculum model integrating cognitive, ethical, and cultural dimensions, and (4) demonstrate practical applications through preservice teacher training examples. This framework provides a model for mathematics teacher education that promotes digital fluency, reflective judgment, and cultural responsiveness (Aprinastuti, 2022). It contributes to ongoing discourse on sustainable, inclusive education by aligning human-centred values with contemporary pedagogical innovation (Carney, 2022; Noddings, 2007).

Method

This study employed a Conceptual Systematic Review (CSR) method, synthesizing literature on CT, RP, and EM published between 2010 and 2025. The

time range (2010–2025) was selected to capture foundational CT frameworks, the rise of reflective pedagogy in teacher education, and contemporary ethnomathematics models employed in both Global South and Global North contexts. Unlike meta-analytic approaches emphasizing statistical synthesis, CSR focuses on theoretical relationships and pedagogical implications (Larrivee, 2000). Databases searched included Scopus, ERIC, and Web of Science using terms such as computational thinking in mathematics education, reflective teaching, ethnomathematics, and preservice teacher curriculum design. Search strategies included explicit Boolean strings: (“computational thinking” AND “preservice teacher”) OR (“CT” AND “mathematics education”), (“reflective pedagogy” OR “reflective practice”) AND “teacher education,” and (“ethnomathematics” AND (“curriculum” OR “teacher preparation”)).

- 1) Inclusion: peer-reviewed articles, book chapters, and theoretical models addressing CT, RP, or EM in teacher education. Additional inclusion criteria required (a) relevance to preservice or initial teacher education, (b) explicit discussion of CT, RP, or EM as a conceptual or instructional construct, and (c) publication in English between 2010 and 2025.
- 2) Exclusion: studies unrelated to mathematics or preservice contexts. Further exclusions included K–12 student-only studies, non-education computational science papers, and ethnographic studies lacking curriculum implications.

A PRISMA-style process guided the identification and screening of studies: 1,462 records were initially retrieved across the three databases, 312 duplicates were removed, 207 titles and abstracts were screened for conceptual fit, and 112 full-text articles were retained for in-depth review.

Thematic synthesis occurred in three stages (Korthagen & Vasalos, 2005):

- 1) Extraction – identifying definitions, theoretical roots, and pedagogical frameworks.
- 2) Mapping – linking shared concepts such as reflection, abstraction, and cultural contextualization.
- 3) Integration – merging results into the conceptual Human-Centred Curriculum Framework (HCCF).

To ensure analytic rigor, the CSR followed six steps: (1) concept untangling, (2) heuristic identification, (3) analytical classification, (4) corpus development, (5) empirical systematization, and (6) synthesis. Quality appraisal used the AACODS tool (Authority, Accuracy, Coverage, Objectivity, Date, Significance), with only studies scoring at least 4/6 included in the final corpus. Illustrative examples from teacher preparation courses were drawn from recent integration models in Indonesia (Aprinastuti, 2022).

Findings and Discussion

CT expands mathematical reasoning through decomposition, abstraction, and algorithmic design (Weintrop et al., 2016; Wing, 2017). In preservice contexts, CT helps student teachers conceptualize problems computationally and design modelling-based lessons that enhance creativity and digital fluency (Angeli et al., 2016; Grover & Pea, 2023). When integrated with reflective strategies, CT promotes not only technical mastery but also critical awareness of technology’s ethical and social implications (Sengupta et al., 2018). In addition, CT can support data-informed decision-making, enabling preservice teachers to examine student

work patterns, identify misconceptions, and justify instructional choices using evidence rather than intuition.

Reflective pedagogy anchors teacher education in ethical awareness and self-regulated learning. Dewey (Dewey, 2006) defined reflection as active, persistent inquiry, while Schön (1983) conceptualized reflection-in-action as critical responsiveness during practice. Within mathematics, RP fosters awareness of how instructional choices impact learners' engagement and identity (Korthagen & Vasalos, 2005). Reflection transforms teaching into a moral practice grounded in social justice and equity (Freire, 1970; Larrivee, 2000).

Ethnomathematics situates mathematical understanding within cultural traditions and lived experiences (D'Ambrosio, 2006; Rosa & Orey, 2016). Integrating EM into preservice education encourages teachers to explore mathematical ideas through indigenous art, local architecture, or community practices (Vithal & Skovsmose, 1997). This contextual approach nurtures inclusive classrooms where mathematics becomes a reflection of diverse human experiences (Boaler, 2016).

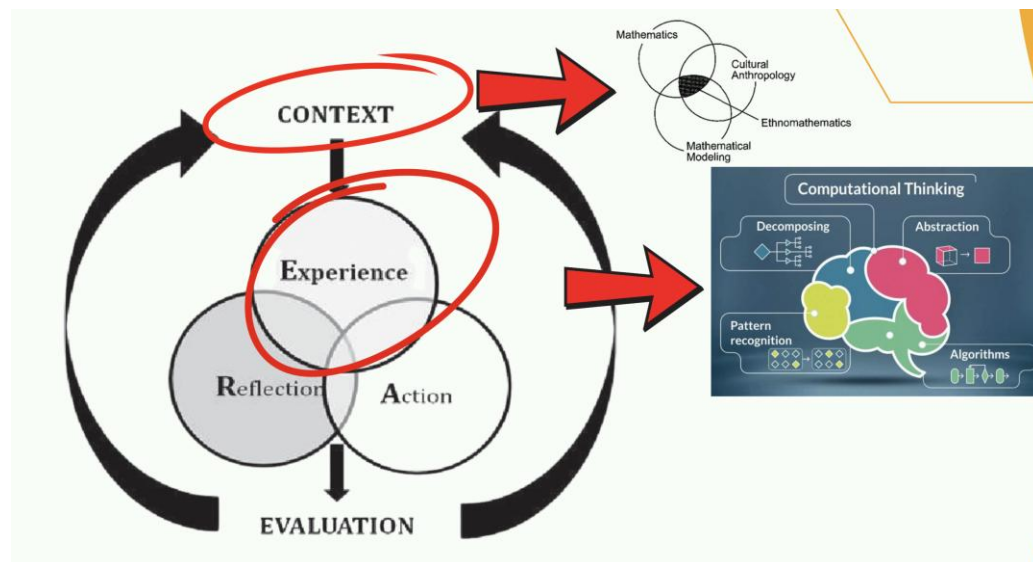


Figure 1. Contextual Approach

The synthesis reveals three key intersections. (1) Reflection ensures ethical, intentional use of digital tools for learning (Sengupta et al., 2018), by requiring preservice teachers to critically evaluate how algorithms, data, and modelling tools affect learners with diverse cultural and linguistic backgrounds. (2) Reflective practice deepens cultural awareness and challenges implicit biases in curriculum design (Larrivee, 2000), prompting teachers to interrogate whose mathematical knowledge is recognized, how culture shapes understanding, and how technological tools may privilege certain ways of thinking. (3) Computational projects grounded in local culture, such as simulating weaving or pattern generation, connect technology with heritage (Aprinastuti, 2021). For example, students can use Python, Scratch, or Blockly to model *batik* symmetries, weaving cycles, or traditional architectural ratios, allowing CT skills to support—not override—cultural authenticity.

Together, these intersections establish the Human-Centred Curriculum Framework, where cognition, reflection, and culture converge. (1) Cognitive Dimension (CT): Problem-solving and abstraction through computational modelling, (2) Ethical-Reflective Dimension (RP): Metacognitive inquiry and value-based decision-making, (3) Cultural Dimension (EM): Contextual, inclusive mathematics grounded in local knowledge.

At their intersection lies human-centred mathematics education—where preservice teachers develop empathy, agency, and cultural respect (Noddings, 2007; Skovsmose, 2011). For instance, preservice teachers designing coding projects that visualize local batik symmetries demonstrate how CT, RP, and EM foster integrated learning and cultural appreciation.

To ensure the framework is measurable, transferable, and suitable for implementation across teacher education programs, the study proposes a multi-layered evaluation plan incorporating quantitative, qualitative, and performance-based metrics. The plan assesses cognitive growth, reflective depth, cultural accuracy, and ethical considerations.

1. Pre/post assessments of CT, RP, and EM competencies. These assessments evaluate conceptual and practical understanding of each dimension. Examples include: (a) CT tasks: debugging algorithms, modelling mathematical patterns in Scratch/Python, (b) RP tasks: analysing classroom evidence and justifying pedagogical decisions. (c) EM tasks: identifying mathematical structures within local cultural practices. Example: A post-test requires modelling a batik motif using transformations and writing a reflective explanation of cultural significance.
2. Classroom performance tasks assessing integration. Preservice teachers design and teach lessons that merge CT, RP, and EM. Assessment rubrics measure: (a) CT processes (abstraction, algorithm design), (b) RP quality (evidence-linked reasoning), (c) EM authenticity (cultural respect and accuracy). Example: Teaching a Grade 4 lesson where students use Scratch to simulate rotational symmetry in a local batik pattern.
3. Fidelity-of-implementation observations during practicum. Observers examine whether preservice teachers enact the framework authentically in classroom settings. Focus areas include: (a) appropriate CT integration, (b) reflective questioning, (c) ethical representation of EM content. Example: A mentor checks whether the algorithmic sequence used to model weaving patterns reflects actual cultural processes rather than oversimplified representations.
4. Reflective journals coded using an evidence-linked rubric. The rubric evaluates: use of student evidence, connections to theory, cultural awareness, and ethical decision-making. Example: High-quality entries reference student work samples and link them to CT or EM principles.
5. Community-based feedback on EM authenticity. Local cultural practitioners validate the accuracy and respectfulness of EM tasks. Example: Batik artisans review computational models to ensure they represent motifs appropriately and respectfully.

This ensures the HCCF remains culturally grounded and ethically responsible.

Conclusion

The Human-Centred Curriculum Framework (HCCF) integrates computational thinking, reflective pedagogy, and ethnomathematics to prepare preservice primary mathematics teachers who are logical, ethical, and culturally grounded. The expanded CSR synthesis demonstrates that CT contributes cognitive tools for modelling and problem-solving, RP cultivates evidence-based professional judgment, and EM ensures curricular relevance rooted in cultural dignity and community knowledge.

A key contribution of this study is the operationalization of the HCCF into implementable curriculum elements—such as computational modelling of cultural patterns, structured reflective journals, community-informed cultural tasks, and ethics-grounded instructional decision-making—which extend existing frameworks like TPACK, TPACK-CT, and critical mathematics education. By providing a concrete evaluation plan with measurable indicators, the framework moves beyond conceptual promise toward practical program design.

The implications for teacher education include: (1) curriculum design: embed coding and digital modelling alongside reflective journaling and ethnomathematical projects. (2) teacher preparation: promote critical, culturally aware, and technologically proficient educators. (3) assessment: Use portfolios, reflective essays, and community-based mathematics projects. Future research should pilot the HCCF in diverse institutional settings, examine its impact on preservice teachers' classroom performance, and explore long-term outcomes for learners in mathematics classrooms. Sustaining the framework will require alignment with national teacher standards, UNESCO's human-centred education agenda, and robust mentoring systems during practicum placements.

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TEACHERS' ETHICAL SKILLS IN THE USE OF AI: A LITERATURE REVIEW ON PRACTICES, CHALLENGES, AND DEVELOPMENT DIRECTIONS IN INDONESIA

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Received: 30 October 2025; Accepted: 28 November 2025

Abstract

Artificial Intelligence (AI) technology has developed rapidly and significantly influenced various aspects of life, including education. One of its impacts is on the role of teachers in utilizing AI within the learning process. The use of AI in education requires teachers to possess ethical skills to ensure that the technology is applied safely, responsibly, and in alignment with moral principles. This study aims to systematically examine the ethical skills of teachers in Indonesia in the context of AI utilization within educational settings. The research employed a literature review method with a qualitative descriptive approach, drawing from various scholarly sources such as accredited journals, academic books, and articles from reputable repositories relevant to the topic. The findings reveal that: (a) teachers' understanding of AI ethical principles remains limited, (b) AI ethical competencies are not explicitly stated in the national teacher competency standards, (c) schools or educational institutions lack specific policies on AI usage, and (d) access to facilities and technology remains uneven across schools. These findings highlight the need to strengthen AI ethics literacy through training programs and the formulation of clear policies to support ethical and inclusive AI implementation in Indonesian education.

Keywords: artificial intelligence, education, ethical skills

Introduction

The era of Society 5.0 marks a significant paradigm shift in human life. In this era, humans, as the central actors of civilization, coexist harmoniously with science and technology. This vision aligns with Indonesia Emas 2045 and its 17 pillars of national development, which include digital transformation and the strengthening of science and technology. Digital technology has advanced rapidly and become widely recognized within society, one of the most prominent examples being Artificial Intelligence (AI).

Artificial Intelligence (AI) was developed with the aim of assisting humans in addressing challenges and performing complex tasks. AI is a computational technology designed to think and solve problems based on data provided by its users (Yani, 2024). The use of AI has expanded rapidly and become an integral part of various sectors, including education. The integration of technology into education is a key factor in building a technology-oriented society, as education serves as the foundation for mastering skills relevant to contemporary demands (Zebua, 2024).



The utilization of AI in the Society 5.0 era presents both opportunities and challenges. In practice, AI can enhance learning effectiveness by providing access to broader, more comprehensive, and easily understandable information and materials (Arifdarma, 2023; Zebua, 2024). Moreover, AI can serve as a learning medium that increases academic productivity and supports adaptive learning that accommodates individual needs and learning styles.

While AI offers significant benefits to education, it also brings potential drawbacks. For instance, tools such as ChatGPT can lead to dependency, addiction, and reduced creativity, potentially replacing human roles in some professions (Akbar, 2025; Farwati et al., 2023). Therefore, the use of AI must be carefully monitored, as excessive dependence may diminish critical thinking skills. Ibad (2024) also highlights that the overuse of AI can raise ethical concerns in academia, including issues of plagiarism.

Teachers play an essential role as facilitators to ensure that AI use in education remains wise and effective. They must address ethical concerns such as student data privacy, algorithmic transparency, equitable access to technology, and the long-term cognitive, social, and emotional effects of AI-based learning. The successful implementation of AI in education requires collaboration among teachers, AI developers, policymakers, students, and communities. Accordingly, ethical skills are essential for teachers to use AI safely, responsibly, and in accordance with moral values. These skills ensure that AI is applied with fairness, inclusivity, and accountability, allowing it to serve as a supportive educational tool without compromising human values.

Several teachers encounter challenges in obtaining sufficient access to technological resources that support the integration of Artificial Intelligence (AI) in education. Essential devices such as computers and other hardware required to operate AI-based platforms are not yet evenly distributed across schools, creating disparities in implementation. In addition, slow or unstable internet connectivity further hinders the development and utilization of AI-driven online learning materials. Beyond access issues, time management also presents a significant obstacle. The adoption of AI-based learning requires additional time for teachers to design and develop instructional materials, which are often more complex and time-consuming than traditional methods. Teachers, who already face tight schedules and numerous teaching responsibilities, must balance these demands alongside administrative duties and other educational activities. Consequently, limited time and unequal technological access remain key barriers to the effective integration of AI in the teaching and learning process.

Ethical skills refer to a set of competencies and ethical awareness that teachers, students, and technology users must possess to ensure that AI utilization is not only effective but also responsible. Teachers play a pivotal role in overseeing AI implementation in educational settings. According to UNESCO (2024), essential teacher competencies related to ethical skills include: understanding ethical principles and responsible AI use, ensuring safety and accountability in AI applications, and formulating regulations and boundaries for AI use. Therefore, this study aims to review literature related to Indonesian teachers' ethical skills in AI utilization while identifying best practices, challenges, and directions for developing teachers' ethical competencies within an AI-based educational ecosystem.

Method

This study employed a literature review method using a qualitative descriptive approach, which aims to provide a detailed overview of AI utilization, teachers' ethical skills in applying AI, and the challenges encountered in this context. The research data were collected from 18 various scholarly sources, including accredited journals, academic books, and articles from official repositories relevant to the research topic. The inclusion criteria for the selected literature comprised publications written in either English or Indonesian, published between 2020 and 2025, and directly related to the themes of ethics and the use of AI within educational settings. To ensure the credibility and validity of the findings, only reputable and peer-reviewed publications were used. Furthermore, literature triangulation was applied by comparing and cross-analyzing findings from previous studies to strengthen the interpretation of results. The data analysis process in this study followed the Miles and Huberman model, which consists of several stages, namely 1) data reduction, involving the selection and simplification of relevant information; 2) data display, which organizes data systematically to facilitate understanding; and 3) conclusion drawing and verification, where patterns, relationships, and insights are identified and validated.

Findings and Discussion

UNESCO (2024) identifies three essential competencies that teachers must possess in relation to ethical skills: 1) ethical principles, including teachers' understanding of AI use; 2) safety and responsibility in its implementation; and 3) formulation of regulations and usage boundaries. Ideally, the application of AI in education should align with these principles outlined by UNESCO.

Ethical Principles

Teachers are expected to have a foundational understanding of ethical issues related to Artificial Intelligence (AI) and the principles necessary for its responsible use. These principles include the protection of human rights, respect for human autonomy and control, and awareness of ethical dilemmas that may arise in educational contexts, such as privacy, human agency, equality, inclusion, cultural and linguistic diversity, and environmental sustainability.

Teachers should be able to map relationships between ethical principles, regulations, and practical examples of AI use through knowledge-mapping tools, while also assessing whether local regulations keep pace with technological advancements. Furthermore, teachers must be sensitive to potential biases embedded in AI systems that could result in injustice or exclusion, particularly for students with disabilities and those from vulnerable groups. When such risks are identified, teachers should report them to the appropriate authorities. Thus, teachers play a critical role in ensuring that AI usage in schools remains inclusive, transparent, and grounded in strong ethical values, contributing to fair and sustainable education.

A study conducted by Rosyanto et al. (2025) in West Java revealed substantial regional disparities in teachers' understanding of AI ethics. The lack of awareness was attributed to ineffective and inconsistent training programs on AI concepts. This finding suggests that awareness of AI ethics remains relatively unfamiliar in Indonesia. Similarly, teachers in Maluku Province face technological barriers that

restrict their understanding of AI applications (Patty & Lekatompessy, 2024). Vorotnykova (2025) also found that teachers' competencies in using AI remain minimal and require targeted professional development programs to improve their capabilities. Teachers' perspectives on AI use must be enhanced so that they can effectively and efficiently utilize existing digital tools. Nevertheless, Putra et al. (2024) discovered that many teachers have successfully integrated AI technologies into their teaching practices, enabling them to design more effective learning strategies.

These variations can be influenced by the readiness of schools to support teachers and students in using AI. The lack of institutional readiness and limited facilities has contributed to uneven implementation of AI ethics among teachers across Indonesia. Additionally, teachers' understanding of AI's potential as a pedagogical partner remains limited, a situation compounded by infrastructure gaps and low levels of digital literacy (Slamet et al., 2025). This suggests that teachers still lack comprehensive knowledge about the effective use of assistive and AI technologies in education.

Safe and Responsible Use

Teachers are expected to understand and apply essential ethical guidelines for the safe and responsible use of AI, including respect for data privacy, intellectual property rights, and legal compliance. They must consistently apply ethical considerations when evaluating and using AI tools, data, and AI-generated content within learning activities. Teachers should also analyze real-world cases to understand threats to AI security both at the design stage (safety by design) and during usage (safety by use). Moreover, teachers must be aware of the legal implications of ethical breaches such as data misuse, copyright infringement, disinformation, and online discrimination. These understandings must be contextualized within local and international regulations to enable teachers to formulate and adapt safe AI-use guidelines suitable for educational settings. In particular, teachers need to ensure data protection for themselves and their students, especially for those with special needs.

Security and responsibility represent key challenges in AI use. Addressing this issue requires collaboration among teachers, parents, and students. Teachers must uphold fairness and ethical principles in developing and applying AI systems to ensure that their benefits are equitably distributed. Through ethical evaluation of AI tools, risk monitoring, and continuous updating of responsible-use guidelines, teachers play an essential role in fostering a safe, ethical, and inclusive learning environment in the age of artificial intelligence. The implementation of AI in Indonesia must therefore prioritize strict privacy management, system transparency, prevention of algorithmic bias, and a balance between technology and human roles, ensuring that education remains human-centered. Furthermore, enhancing digital and AI literacy among both teachers and students is crucial for successful implementation.

Mandatory professional training should include both technical skills and pedagogical approaches to promote responsible AI use. From a governance perspective, the absence of comprehensive AI regulation in Indonesia poses serious risks related to data privacy, algorithmic fairness, and system accountability. Consequently, policy frameworks must establish clear standards for data collection,

storage, and usage in accordance with international privacy principles, ensuring protection from third-party misuse. Teachers also serve as key agents in promoting AI ethics through critical thinking and proactive engagement, such as leading classroom discussions and organizing activities that highlight ethical, social, and environmental issues in AI development and application. Teachers should also participate in drafting and revising ethical guidelines for AI use in education, ensuring that such frameworks reflect inclusivity and social justice.

They are encouraged to investigate how AI influences social equity, economic opportunity, environmental sustainability, and cultural and linguistic diversity, particularly regarding its implications for vulnerable groups. Teachers should critically review AI tool guidelines to ensure that they align with ethical principles and mitigate potential harm, providing constructive feedback for improvement. By participating in ethical policy dialogue and collaborative regulation development, teachers can become pioneers in promoting ethical, inclusive, and responsible AI practices in education.

Policy Formulation and Usage Boundaries

The use of AI in Indonesian education particularly the increasing adoption of ChatGPT presents several limitations that must be carefully addressed 1) teachers and students require direct interaction during learning, which ChatGPT cannot provide; 2) creativity is essential in learning; excessive reliance on ChatGPT may reduce originality, as the tool lacks human creativity; 3) ChatGPT cannot accommodate diverse individual learning styles; 4) continuous use may weaken critical thinking and social interaction skills; 5) individuals may become overly dependent on technology, leading to cognitive passivity.

Sucianingtyas et al. (2025) argue that overuse of AI can create social problems, such as increased unemployment, diminished creativity reliant on programmers, reduced human interaction, technological dependency, high implementation costs, and declining motivation among young learners. Similarly, Ibad (2024) notes that AI overuse can result in academic ethical issues, including plagiarism. AI, therefore, cannot fully replace the teacher's role. Instead, teachers should maximize the benefits of AI to enhance the effectiveness and efficiency of learning, helping students reach their full potential. To mitigate negative impacts, clear boundaries must be established. The government and educational institutions must formulate written and enforceable policies to ensure that AI benefits learning without becoming detrimental to teachers or students. At Sekolah Cikal, learning is implemented through a project-based approach, allowing students to spend more time creating and collaborating. Therefore, the use of gadgets is not continuous. The school also provides a gadget storage cabinet so that students only take their devices when technology is truly needed for learning. This approach helps students stay focused and reduces excessive screen dependency. Sekolah Cikal strives to create a learning environment that fosters critical thinking, responsible actions, and the ethical use of technology. The use of AI is carried out carefully and always directed toward clear learning purposes. These simple steps reflect Sekolah Cikal's commitment to ensuring a balanced and responsible use of technology and AI.

Based on the research findings, it was identified that teachers' ethical principles remain relatively low. In terms of safe use, teachers demonstrate awareness and concern in collectively protecting students' personal data and

utilizing technology safely; however, it cannot be denied that some data have been widely disseminated due to negligence by certain parties. Meanwhile, regarding the formulation of regulations and policies, no written guidelines have been found to serve as a reference for teachers in utilizing AI. Teachers have the freedom to use AI without clear boundaries or limitations. The successful integration of AI in Indonesia's education system depends on the synergy between infrastructure policies, digital literacy, ethical governance, and collaboration among multiple stakeholders. Each ethical component, principle, responsibility, and regulation is interrelated and cannot stand alone. Teachers are expected to master all ethical skill principles comprehensively. Through a holistic policy framework, AI can become a transformative tool for achieving equitable, adaptive, and inclusive education for all members of society.

Conclusion

In the era of Society 5.0, Artificial Intelligence (AI) has rapidly advanced and become increasingly integrated into various aspects of life, including education. The use of AI in education has brought both positive and negative impacts, including within the Indonesian context. Optimal implementation of AI in education must take into account multiple dimensions and competencies, particularly the ethical skills that teachers are expected to possess. The findings of this study indicate that 1) teachers' understanding of AI ethical principles and their ability to use AI safely and responsibly remain limited; 2) ethical and digital safety aspects are not yet explicitly included in the national teacher competency standards; 3) schools lack specific policies regulating AI use; and 4) access to facilities and technology remains uneven across schools. Therefore, it is essential to strengthen AI ethics and safety literacy through teacher training programs, revise competency standards to incorporate ethical and digital responsibility components, and develop AI governance policies that emphasize transparency, data privacy, and equitable access to support inclusive and sustainable education in Indonesia. In addition, a national guideline is needed to regulate the use of AI in schools. Schools should also establish a team to monitor AI implementation to ensure it remains safe and ethical. Collaboration with external partners can further support teachers in developing their technological competencies. It is also important to introduce AI literacy to students from an early stage. These efforts are expected to promote more appropriate and responsible use of AI within the educational environment.

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USING IN-SITU SIMULATION IN UNDERGRADUATE NURSING CLINICAL EXAMINATION: LESSONS AND PERSPECTIVES OF EDUCATORS AND STUDENTS FROM SULTAN QABOOS UNIVERSITY, OMAN

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Received: 31 October 2025; Accepted: 21 January 2026

Abstract

Undergraduate nursing education traditionally separates theoretical learning from clinical practice, often creating a gap between what students learn and how they apply it in real settings. To bridge this gap, simulation has emerged as a powerful tool for integrating theory and practice while enhancing students' problem-solving skills. In-situ simulation, conducted within hospital environments, was introduced in Fall 2022. The objectives of this study are (1) to explore students' and faculty's experience with using in-situ simulated examinations, (2) to identify challenges and lessons from using in-situ simulated clinical examinations, and (3) to identify strategies to improve in-situ simulated clinical hospital-based examinations. Qualitative data were collected from eight student focus group interviews and eight in-depth interviews involving faculty members. Participants were purposively selected, and informed consent was obtained before data collection. A reflexive thematic analysis approach was used to analyze participant data. In-situ simulation provided authentic, real-life learning opportunities that better reflected clinical realities. The experience was both challenging and rewarding, since hospital-based simulations exposed learners to real noise, distractions, and teamwork dynamics. Educators were also able to assess students' performance under realistic conditions. The study concludes that in-situ simulation should be prioritized in nursing education as it effectively bridges the theory-practice gap and prepares students for the complexities of real clinical environments.

Keywords: clinical competence, nursing, nursing education, simulation training, students, teaching methods

Introduction

Simulation-based education has become a cornerstone in modern nursing curricula, bridging the gap between theoretical knowledge and clinical practice.



Among various simulation modalities, in-situ simulation (ISS)-defined as simulation conducted in the actual clinical environment with real teams and equipment- has gained traction due to its ecological validity and practical relevance (Pritchard & Sirbu, 2024). ISS enables learners to experience high-fidelity, context-rich scenarios that mimic real patient care, facilitating both technical skill acquisition and team-based competencies such as communication and critical decision-making (Gu et al., 2024).

In nursing education, the integration of ISS has been shown to enhance preparedness for clinical emergencies and improve performance in high-stakes evaluations (Tran & Bradley, 2025; Nguyen et al., 2024). Studies have emphasized the value of ISS not only in improving clinical knowledge but also in developing confidence and reducing anxiety among nursing students (Al-Abri et al., 2025). Furthermore, the role of educators in designing, delivering, and debriefing ISS sessions is crucial, influencing both pedagogical outcomes and the sustainability of simulation-based assessment (Notario et al., 2024).

Despite growing global evidence, the exploration of ISS in Middle Eastern academic contexts, particularly within the Gulf region, remains limited. Cultural, institutional, and infrastructural factors shape how ISS is implemented and perceived. In Oman, nursing education has progressively adopted innovative methods; however, what remains unknown are insights into faculty perspectives on ISS-based clinical examinations. This study explored nursing educators' experiences and perceptions of using in-situ simulation as an assessment strategy in undergraduate nursing programs. Understanding these perspectives is essential for developing sustainable, context-sensitive simulation frameworks that align with both global best practices and local educational imperatives. As a unique contribution, these findings demonstrate that In-situ simulation: a) is an effective method for summative assessment; b) requires effective coordination of standardized patients (SPs) in hospital settings for optimal outcomes; c) has implications for responsive institutional policy and faculty workload allocation.

Method

Design

This study employed an integrated qualitative research design, which offers flexibility by integrating elements of multiple qualitative traditions without being confined to one specific framework (Kahlke, 2014). This approach is especially useful in applied educational contexts, where the aim is to explore subjective experiences and generate practice-relevant insights (Ellis & Hart, 2023). The study focused on understanding clinical nurse educators' perspectives on the use of in-situ simulation (ISS) for undergraduate clinical examinations at Sultan Qaboos University in Oman.

Setting and Context

The research was conducted at the College of Nursing, Sultan Qaboos University, in collaboration with the Sultan Qaboos University Hospital (SQUH) and Sultan Qaboos Comprehensive Cancer and Research Center (SQCCRC). The first in-situ simulated examinations took place at the College of Nursing during the Fall 2022 semester within the Nursing Administration Clinical Course. This innovative approach to student clinical evaluation involved utilizing standardized

patients in actual clinical settings, and this represented a significant pedagogical shift from traditional laboratory-based simulation models.

Participants and Sampling

The study population consisted of nursing faculty involved in clinical teaching and assessment for the Nursing Administration Clinical Course during the study period. A purposive sampling strategy was used to recruit educators by an assigned clinical instructor. The recruited faculty were those who were directly involved in designing, facilitating, or evaluating the ISS-based assessments. Sampling was informed by the information power of participants, a concept that aligns with the concept of data saturation (Malterud et al., 2016; Faulkner & Trotter, 2017; Rahimi & Khatooni, 2024). A total of eight clinical instructors participated as key informants in the study. The eight interviews were considered sufficient as the data reflected homogeneity, focus, and data richness, and it allowed the team to effectively interpret faculty perspectives through dialogic discourse (Sullivan 2012).

Data Collection

Data were collected using semi-structured, in-depth interviews, guided by an interview protocol grounded in the study objectives. The interviews were conducted face-to-face in a quiet, private setting to ensure comfort and confidentiality. In addition, each participant was anonymized using a code that protected their identity. The audio data was carefully stored under password protection, and the field notes were kept under lock by the Principal Investigator to ensure data privacy and allow for further scientific inquiry when the need arises. Each session lasted between 45 and 60 minutes and was conducted in English. Interviews were audio-recorded with participant consent and complemented by detailed field notes taken by the research team. The interview guide explored educators' experiences with ISS, perceived advantages and disadvantages, encountered challenges, and recommendations for improving future simulated assessments. The educators were asked to be objective in their comments.

Ethical Considerations

Ethical approval was obtained from the College of Nursing Research and Ethics Committee at Sultan Qaboos University (CON/DF/2022/12). Participants provided written informed consent prior to data collection. Participation was voluntary, and confidentiality was maintained through the use of code and secure storage of digital files. Participants were also informed of their right to withdraw without any academic or professional consequences.

Data Analysis

Data were analyzed using the reflexive thematic analysis method (Braun & Clarke, 2016; Braun et al., 2016), which entailed six phases: familiarization with data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report. The transcripts were read multiple times by members of the team to ensure immersion. Codes were first independently generated, then collaboratively compared and refined through team discussions. An iterative approach was taken, allowing themes to emerge from the data rather than

imposing them before immersion into the data. In addition, the team also engaged in dialogic coding and reflexivity, besides observing trustworthiness and credibility strategies recommended by Lincoln and Guba (1985), such as peer debriefing and maintaining audit trails. The final themes emerged out of a shared understanding that resulted from the collaborative coding of the team.

Findings

A total of eight clinical nurse educators participated in the study, all of whom had supervised and/or evaluated students during both traditional laboratory-based simulations and the newly implemented in-situ simulation (ISS) model using standardized patients in actual clinical settings. A detailed thematic analysis revealed four core themes and associated subthemes that reflect the educators' experiences, insights, and recommendations as highlighted below:

Theme 1. Enhanced Realism and Clinical Relevance

Participants overwhelmingly reported that ISS added a dimension of real-world authenticity to the examination process that was previously missing from lab-based simulations.

*“The realism in ISS is unmatched. The hospital setting, the noise, the unpredictability, it brought out more authentic student behavior”
(Participant 3)*

The clinical instructors observed that students demonstrated more situational awareness, professional demeanor, and adaptability when examined in the actual hospital environment. Most clinical teachers reported that examining students alongside the routine ward activities allowed for better assessment of critical thinking and clinical judgment of each student.

*“In the lab, they are rehearsed. In the ward, they have to think on their feet, and you get to see their actual behaviour.”
(Participant 1).*

Theme 2. Logistical and Operational Challenges

Despite the perceived pedagogical value, educators described multiple logistical barriers associated with conducting ISS, the most outstanding being related to space and coordination.

Space and Scheduling Conflicts

The educators reported that some wards lacked private areas to conduct the examination, and sharing clinical spaces with hospital staff required detailed coordination.

“It was hard finding an uninterrupted space in the ward, especially during peak hours.” (Participant 4).

Such gaps identified the need for better integration with hospital workflows in the future.

Standardized Patient Coordination

The participants reported that while the use of SPs was beneficial, implementing this innovative approach to student evaluation required more training before the actual examination:

“Some SPs were unsure how much to say or when to react-it impacted the flow.” (Participant 4)

These limitations highlighted the importance of investing in simulation fidelity, including preparatory sessions for SPs.

Theme 3. Educator Professional Growth Opportunities

The ISS experience also prompted educator self-reflection and professional growth. Participants described developing a richer appreciation for assessment in complex clinical contexts.

“I learned more about my own biases in clinical evaluation... ISS challenged me too” (Participant 5)

Educators also appreciated the collaborative debriefing processes, which allowed them to calibrate their evaluations and discuss observed student behaviors from multiple angles.

“During the debriefing, I realized how much I could learn from my colleagues’ perspectives. It felt like we were all teaching and learning from each other” (Participant 8)

Theme 4. Sustainability of Simulated Experiences

Participants offered clear strategies to enhance ISS as a sustainable examination approach.

Subtheme 4.1: Institutional Support

“We need administrative backing—dedicated spaces, time, trained SPs, and recognition of the workload.” (Participant 3)

The introduction of ISS was time-intensive and required administrative acknowledgment of faculty effort, suggesting a need for policy integration, including rethinking faculty reward.

Subtheme 4.2: Structured Orientation for Students and SPs

The clinical educators emphasized that student preparedness and SP training were both pivotal to the success of ISS.

“Some students were nervous. If we orient them better, they’ll be more confident.” (Participant 2)

Some suggestions by the clinical educators included conducting simulation readiness workshops and interdisciplinary dry runs prior to high-stakes assessments in the future.

Discussion

This qualitative descriptive study explored the perspectives of clinical nurse educators on the implementation of in-situ simulation (ISS) using standardized patients (SPs) for undergraduate nursing assessment in Oman. This study was an attempt to address the tension between “realism” in clinical practice and the need for “standardization to ensure assessment validity” in undergraduate education. The findings revealed that educators perceived ISS as a powerful pedagogical tool that enhanced realism, improved assessment of clinical competence, and promoted reflective teaching practice. However, they also acknowledged logistical and operational barriers that require institutional support for better integration.

Enhancing Realism and Clinical Relevance

Educators highlighted ISS as superior to traditional lab-based simulated examination due to its authenticity and contextual fidelity. This finding aligns with reports by Martin, Cross, and Attoe (2020), who noted that ISS offers learners exposure to actual clinical environments, enabling better preparation for real-world scenarios. Similarly, Brandstorp et al. (2016) found that in-situ training fosters more effective learning transfer by embedding simulation within real clinical workflows. ISS in clinical practice is increasingly being used to improve students’ professional competencies and to foster interdisciplinary practice because of its positive outcomes, such as improved patient morbidity and mortality, improvement in clinical skills, and better organizational performance (Goldshtein et al., 2019; Martin et al., 2020).

The perceived benefit of ISS in bridging the theory–practice gap has been a persistent theme in the literature. Hashemiparast et al. (2019) reported that disconnects between classroom learning and clinical application remain a challenge in nursing education. ISS directly addresses this issue by allowing students to apply knowledge in realistic, high-stakes environments, promoting decision-making and situational adaptability (Eyikara & Baykara, 2017; Chang et al., 2022). This innovative approach allows for skill enhancement. In further support, Karlsen et al. (2024) in a recent study reported that undergraduate nursing students found ISS as being very instrumental in supporting their learning process, and most importantly, it helped them to firmly connect theory and practice, which ultimately enhanced their overall confidence in performing clinical skills.

Logistical and Operational Constraints

Despite its benefits, educators encountered practical challenges, including space limitations, staffing limitations, financial costs, scheduling conflicts, and the need for better-prepared SPs. These barriers are consistent with those reported by Kurup et al. (2017), who observed that ISS often competes with ongoing clinical activities, making implementation complex in active hospital settings. Similarly, Venkat and Deering (2025) reported that ISS is often affected by barriers such as unit acuity, staffing limitations, financial costs, and scheduling disruptions, which

might make implementation challenging for educators. The scholars recommend that educators seek leadership support and incentivize participation in ISS.

In terms of operations, Fan et al. (2016) emphasized the importance of pre-simulation coordination and rehearsal with SPs to mitigate performance inconsistencies that may affect learner assessment. These findings also support those of Cook et al. (2018), who argued that while ISS is cost-effective in the long run, initial investments in training, faculty development, and interdepartmental collaboration are essential for effective implementation.

Educator Professional Growth Opportunities

The findings reveal that ISS served as a platform for faculty learning and introspection far beyond serving as an assessment opportunity in the clinical area. This finding supports Stewart et al. (2017), who describe reflective immersion in authentic contexts as key to advancing pedagogical expertise. Educators in this study reported greater awareness of their own assessment practices and recognized opportunities to recalibrate expectations through collaborative debriefing. These outcomes underscore ISS as not only a student learning tool but also a faculty development strategy, echoing arguments by Lavelle et al. (2017).

In a recent publication, Karlsen et al. (2024) noted that ISS often serves as a bidirectional learning platform, where learners strengthen their clinical judgment and teamwork and related skills, while educators simultaneously refine skills related to debriefing, assessment techniques, and gain systems awareness through structured, psychologically safe, and standards-aligned reflective practice. The researchers conclude that this dual impact justifies positioning ISS not only as a pedagogical method but as a strategic pillar of faculty development (Hallmark et al., 2021; Brazil et al., 2023; Soni et al., 2024).

Sustainability of Simulated Experiences

Participants emphasized the importance of administrative support and structured orientation for both SPs and students to ensure the sustainability of simulated learning and assessment. These insights reinforce findings by Goldshtein et al. (2019), who concluded that sustainable ISS implementation requires dedicated resources, leadership backing, and staff recognition. Additionally, Kelsey and Claus (2016) advocate for institution-wide commitment to simulation integration, including formalized policies and logistics frameworks to ensure continuity and quality.

Indeed, recommendations from the current study - including dedicated simulation time in clinical rotations, SP training modules, peer coaching, and workshop-based simulation readiness workshops - reflect strategies advocated in the literature (Mulyadi et al., 2021; Al Gharibi et al., 2021; Soni et al., 2024). For instance, Roussin et al. (2024) emphasize readiness planning to integrate simulation into clinical rhythms rather than treating it as an extraneous activity; such planning ensures simulation is not marginalized but embedded in workflow. Seethamraju et al. (2021) observe that these corrective interventions can enhance educators' facilitation confidence and reflective practice, resulting in better simulation outcomes.

Implications for Practice and Education

The findings of this study have implications for nursing education programs in Oman and beyond. ISS offers a contextually grounded model for evaluating student competence, particularly in high-stakes clinical areas such as nursing administration. Educational leaders should consider embedding ISS into course design and clinical evaluations, ensuring adequate preparation, support, and evaluation mechanisms for all stakeholders involved.

Limitations

This study was limited by its single-site design and relatively small sample size, which may affect the generalizability of findings. However, consistent themes and rich narratives support the credibility of results. Another possible limitation is the social-desirability bias, which might have occurred as the instructors were involved in the ISS. This second limitation was addressed by neutrally framing questions. Future research involving students, multiple institutions, and comparative outcome measures would strengthen the evidence base on ISS efficacy in education.

Conclusion

This study explored the experiences of nurse educators in implementing in-situ simulation (ISS) with standardized patients for clinical assessments of undergraduate nursing students in Oman. The results affirm that ISS offers a powerful learning and assessment modality by immersing students in real clinical settings, enhancing contextual learning, improving performance realism, and bridging the long-standing theory–practice gap in nursing education.

However, the integration of ISS also revealed logistical, organizational, and faculty development challenges. These underscore the need for a structured, well-supported implementation framework. Faculty development, simulation coordination, adequate SP training, and sustained administrative support emerged as essential factors in successful ISS delivery.

This study provides evidence that ISS not only benefits students but also stimulates reflective practice among educators, making it a dual-purpose innovation for assessment and faculty growth. If carefully planned and supported, ISS can revolutionize simulation-based learning in undergraduate nursing programs in Oman and similar contexts worldwide.

Key Takeaways/ Contribution:

- In-situ simulation enhances assessment authenticity and improves student performance under real-life clinical pressures.
- Educators benefit professionally, using ISS as a tool for reflective practice and instructional refinement.
- Sustainability requires structured support, including administrative alignment, orientation modules, and clear simulation policies.
- Ongoing SP training and calibration are critical for ensuring standardization, fairness, and validity in assessments.
- ISS is best embedded longitudinally, within course curricula, not as a one-time intervention for both in-course skills training and summative student evaluation.

Ethical Declaration

The study was approved by the Sultan Qaboos University, College of Nursing, Research and Ethics Committee (CON/DF/2022/12), and all participants provided consent to participate.

Acknowledgements

The authors acknowledge the generous time and effort provided by their study participants.

Funding Declaration

Funding was received from the Sultan Qaboos University, College of Nursing Dean's Fund.

Conflict of Interest

The authors of the manuscript declare no conflict of interest.

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THE EFFECT OF NUMBERED HEADS TOGETHER (NHT) AND PROBLEM CARDS ON 10TH GRADE STUDENTS' COLLABORATION AND COMMUNICATION SKILLS

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Received: 30 October 2025; Accepted: 30 November 2025

Abstract

This study aimed to determine the effect of the Numbered Heads Together (NHT)-type cooperative learning model assisted by Problem Card media on the collaboration and communication skills of class X students of SMA Negeri 10 Semarang. The type of research used is a quasi-experimental with a Posttest-Only Control Group Design. The research sample consisted of students in classes X-9 (control class) and X-10 (experimental class), each totaling 35 students. Data were collected using an observation sheet and a questionnaire. Data analysis used the Independent Sample t-Test. The results obtained were an Asymp. Sig. (2-tailed) value on the observation sheets and questionnaires of $0.000 < 0.05$. Therefore, H_0 is accepted, which indicates that the NHT type cooperative learning model assisted by Problem Card media has an effect on the collaboration and communication skills of class X students in biology learning at SMA Negeri 10 Semarang. Further researchers can examine the comparative effectiveness of the NHT learning model assisted by problem cards with other cooperative models on students' collaboration and communication skills in other materials or lessons.

Keywords: collaboration skills, communication skills, numbered heads together (NHT), problem cards.

Introduction

Collaboration and communication skills are two of the four key competencies of the 21st century, known as the 4Cs, namely communication, collaboration, critical thinking, and creative thinking. Collaboration and communication skills are basic skills that every individual must possess in order to more easily adapt to future global competition (Dhitasarifa et al., 2023).

Collaborative skills refer to the ability of individuals to work together effectively to achieve desired goals. Collaborative skills play an important role in improving learning effectiveness. Students will find it easy to share knowledge and experiences, support each other, and solve problems wisely if they have good collaborative skills (Thahir et al., 2024). Afelia et al. (2023) revealed that 10th-grade students at SMAN 1 Bangorejo had low collaboration skills in biology learning. This was evident during ineffective group discussions, where only one out of five groups was able to divide tasks and discuss well. Meanwhile, other groups showed less collaborative work patterns, with two groups being worked on by one



individual, one group working independently, and another group exceeding the specified time limit. Collaboration skills can be effective if communication between students is also clear and open. This makes communication skills important for students to have in the learning process.

Good communication skills enable a person to convey ideas clearly, interact effectively, and form strong relationships (Miranda & Wahyudin, 2023). Hamia (2021) revealed that effective communication skills are important for student learning success because they make it easier for them to communicate various material issues, both verbally and in writing. Nashiruddin et al. (2024) stated that PAI learning in class XII at SMA N 5 Padang did not facilitate students' communication skills. This was evident from the lack of active participation of students in asking and responding to questions, resulting in passive learning and low curiosity among students. Tauzirie and Nurhadi (2025) also revealed that the communication skills possessed by 10th-grade students at Darussalam Wanaraja High School were ineffective due to a lack of experience speaking in public and a fear of receiving unpleasant feedback from others.

This condition was also identified in 10th-grade students at SMA Negeri 10 Semarang in biology lessons. Based on the results of preliminary research conducted by the researcher, it was found that students did not contribute much to group assignments, as they were busy with their own activities, paid little attention when the teacher was explaining, and had poor time management, so that assignments were often not completed on time. During discussions, students tended to remain silent, rarely expressed their opinions, and some groups were late in submitting or had difficulty presenting their assignments. In addition, the lack of focus among students resulted in a lack of questions or responses to the teacher, making the learning process less interactive. Therefore, students need to be trained to optimize their collaboration and communication skills.

Collaboration and communication skills can be optimized through a learning model approach that not only makes it easier for students to understand the material but also encourages cooperation and effective interaction. One learning model that can train students' collaboration and communication skills is the cooperative learning model. The cooperative learning model emphasizes cooperation and active student participation. Kurniasih (2023) explains that cooperative learning is a way for students to work together in small groups and support each other during the learning process. One effective cooperative learning model that fosters cooperation and active student participation is Numbered Heads Together (NHT).

The NHT cooperative model is a learning method that involves grouping students to solve problems and assigning different identification numbers to each group member, who are then randomly selected to present the results of their discussion in front of the class (Asmoro et al., 2023). This model can help students develop their communication skills in sharing information, speaking in a structured manner, and listening carefully, thereby increasing their learning effectiveness (Karmila & Mawardi, 2020). The NHT model is also capable of supporting students' collaboration skills by increasing their engagement when answering questions, interactions between students, accountability, and individual responsibility within the group.

The learning model will be successful if combined with learning media to increase student motivation and learning interaction (Situngkir et al., 2023).

Learning media is essentially a means of conveying information from the communicator (teacher) to the communicant (student). Its main function is to create an environment that enables students to understand knowledge accurately and deeply, improve their thinking skills, and shape their attitudes and personalities (Saleh et al., 2023). One type of media that is effective in assisting the learning process is problem cards.

Problem cards are a type of visual media that contain problems to encourage students to actively speak and become interested in the topic of the material (Tohari, 2021). Himmawati (2022) revealed that this media not only presents problems related to lessons but also effectively trains students' communication skills through active discussion. Problem cards are used as additional activities and group assignments that must be completed and presented with solutions (Dewi et al., 2020). Research by Ahtina et al. (2024) shows that card-based learning media using the STEM approach is effective for training students' collaboration skills. Alfira and Izzah (2024) stated that the use of problem cards can significantly develop students' communication skills in the context of science learning, marked by an increase in the ability to construct arguments, present information, and respond to questions with more confidence and clarity.

Research by Nurjannah and Djumadi (2023) shows that the application of the NHT learning model combined with question cards is considered capable of stimulating student activity, creating a pleasant learning atmosphere, and triggering competitive spirit among groups to solve problems. Nourhasanah and Aslam (2022) further explain that the application of the NHT model specifically encourages students to be active, creative, and able to explore their understanding. This model not only affects learning outcomes but also increases interaction among peers in discussions, thereby directly training and developing students' collaboration and communication skills.

Based on this description, the purpose of this study is to analyze the effect of the NHT cooperative learning model assisted by problem cards on the collaboration skills of 10th-grade students at SMA Negeri 10 Semarang. The results of this study are expected to provide an overview of the effect of implementing the NHT cooperative learning model supported by problem cards in optimizing students' collaboration and communication skills.

Method

This study used a quantitative approach, with a quasi-experimental design and a posttest-only control group design. The research design is presented in the following table.

Table 1. Research Design		
Class		Treatment
Experimental	X1	O1, O2
Control	X2	O1, O2

Data collection for this study was conducted at SMA Negeri 10 Semarang in the even semester of the 2024/2025 academic year. The population in this study consisted of all 10th-grade students, comprising 10 classes with a total of 355 students. Sampling was conducted using non-probability sampling with purposive

sampling. The control and experimental classes were determined based on the results of the ANOVA test on the students' Final Semester Assessment (PAS) scores to ensure the similarity of academic abilities and initial skills between the two classes. The sample used as the control class was X-9, which applied the discovery learning model, and the experimental class was X-10, which applied the NHT model assisted by problem cards. The considerations of the 10th grade Biology teacher were also taken into account in determining the sample.

The instruments used to measure students' collaboration and communication skills are non-test instruments, including observation sheets and questionnaires. The content validity of the observation sheets and questionnaires was tested by experts and found to be valid and suitable for use in research. The research data were then analyzed using the Independent Sample t-Test (IBM SPSS 24, $\alpha = 0.05$), after ensuring that the data were normally distributed and had a homogeneous variance.

Findings and Discussion

Findings

The data from the descriptive statistical analysis of the collaboration and communication skills of students in the control and experimental classes based on observation sheets and questionnaires are presented in Table 2.

Table 2. Descriptive Statistical Results of Collaboration Skills
Based on Observation Sheets and Questionnaires

Data Source	Class	N	Minimum	Maximum	Mean	Std. Deviation
Observation	Control	35	36	95	66,51	13,373
	Experiment	35	57	98	83,51	9,373
Questionnaire	Control	35	56	84	70,00	6,691
	Experiment	35	65	97	81,20	7,776

Table 2 shows that the results of observations and questionnaires in the experimental class had a higher average score than the control class in terms of collaboration skills.

Table 3. Descriptive Statistics Results for Communication Skills
Based on Observation Sheets and Questionnaires

Data Source	Class	N	Minimum	Maximum	Mean	Std. Deviation
Observation	Control	35	27	96	67,20	14,142
	Experiment	35	50	100	82,29	10,191
Questionnaire	Control	35	51	80	64,51	6,409
	Experiment	35	62	84	71,20	5,263

Table 3 shows that the results of observations and questionnaires on communication skills in the experimental class had a higher average score than the control class. After obtaining these data, the analysis then continued with prerequisite tests consisting of normality tests, homogeneity tests, and independent

sample t-tests. The data from the normality tests of students' collaboration and communication skills are presented in Tables 4 and 5.

Inferential Statistical Analysis

Normality Test

Normality tests are conducted to determine whether the distribution of the data obtained is normal or not (Khudriyah, 2021). Data normality was tested using Kolmogorov Smirnov through IBM SPSS version 24 application. The condition is that if the Sig. value is > 0.05 , it can be interpreted that the data is normally distributed, while if the Sig. value is < 0.05 , the data is not normally distributed. The results of the normality test are presented in Table 4.

Table 4. Results Of Normality Test for Observation Sheets on Collaboration and Communication Skills

<i>Kolmogorov-Smirnov</i>		
	Class	Sig.
Collaboration Skills	Kontrol	.074
	Eksperimen	.200
Communication Skills	Kontrol	.115
	Eksperimen	.139

Table 4 shows the results of the normality test of the observation sheets for collaboration and communication skills in the control and experimental classes, which overall have a Sig. value $> \alpha = 0.05$, so the data is said to be normally distributed.

Table 5. Normality Test Results for The Collaboration and Communication Skills Questionnaire

<i>Kolmogorov-Smirnov</i>		
	Class	Sig.
Collaboration Skills	Kontrol	.130
	Eksperimen	.200
Communication Skills	Kontrol	.200
	Eksperimen	.155

Table 5 shows the results of the normality test of the questionnaire sheets for collaboration and communication skills in the control and experimental classes. The overall significance value of the data obtained is greater than $\alpha = 0.05$, indicating that the data is normally distributed. Thus, it can be continued with the homogeneity test as presented in Tables 6 and 7.

Homogeneity Test

The homogeneity test was conducted to determine whether the data variance of each group was the same or not. This calculation used the One-Way Anova test with the help of IBM SPSS version 24. Decisions with a Sig. value > 0.05 were declared homogeneous, and those with a Sig. value < 0.05 were declared non-homogeneous.

Table 6. Results of the Homogeneity Test for the Collaboration and Communication Skills Observation Sheet

<i>Test of Homogeneity of Variances</i>				
	<i>Levene Statistic</i>	<i>df1</i>	<i>df2</i>	<i>Sig.</i>
Collaboration Skills	2.023	1	68	.159
Communication Skills	2.169	1	68	.145

Table 6 presents the results of Levene's homogeneity test on the observation sheet, which shows that the significance value for each skill is greater than 0.05. This indicates that the variance between learning models for both skills is homogeneous.

Table 7. Results of the Homogeneity Test for the Collaboration and Communication Skills Questionnaire Sheet

<i>Test of Homogeneity of Variances</i>				
	<i>Levene Statistic</i>	<i>df1</i>	<i>df2</i>	<i>Sig.</i>
Collaboration Skills	.647	1	68	.424
Communication Skills	1.234	1	68	.270

Table 7 presents the results of Levene's homogeneity test on the questionnaire, which shows that the significance value for each skill is greater than 0.05. This indicates that the variance between learning models for both skills is homogeneous. If the data meet the assumptions of normality and homogeneity, the analysis will continue with the Independent Samples t-Test presented in Tables 8 and 9.

Independent Sample t-Test

Table 8. Results of Independent Sample t-Test Analysis of Collaboration and Communication Skills Observation Sheet

		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2- tailed)	Mean Difference
Collaboration Skills	Equal variances assumed	2.023	.159	-6.159	68	.000	-17.000
	Equal variances not assumed			-6.159	60.908	.000	-17.000
Communication Skills	Equal variances assumed	2.169	.145	-5.120	68	.000	-15.086
	Equal variances not assumed			-5.120	61.813	.000	-15.086

Table 8 shows the results of the Independent Sample T-Test based on the observation sheet, in the Equal variances assumed row, obtaining a Sig. (2-tailed) value of 0.000. The significance value of $0.000 < 0.05$, so H_0 is rejected, and H_a is accepted. This shows that there is an effect of the NHT learning model assisted by problem cards on the collaboration and communication skills of grade X students at SMA Negeri 10 Semarang.

Table 9. Results of Independent Sample t-Test Analysis of Collaboration and Communication Skills Questionnaire

		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Collaboration Skills	Equal variances assumed	.647	.424	-6.459	68	.000	-11.200
	Equal variances not assumed			-6.459	66.520	.000	-11.200
Communication Skills	Equal variances assumed	1.234	.270	-4.769	68	.000	-6.686
	Equal variances not assumed			-4.769	65.518	.000	-6.686

Table 9 shows the results of the Independent Sample T-Test based on the questionnaire, in the Equal variances assumed row, obtained a Sig. (2-tailed) value of 0.000. The significance value of $0.000 < 0.05$, so H_0 is rejected, and H_a is accepted. This shows that there is an effect of the NHT learning model assisted by problem cards on the collaboration and communication skills of grade X students at SMA Negeri 10 Semarang.

The results of observations of each indicator of collaboration and communication skills in the control and experimental classes are presented in Tables 10 and 11 below.

Table 10. Results of Observations of Collaboration Skill Indicators in the Control and Experimental Classes

Collaboration Skills Indicators	Average Score	
	Control Class	Experimental Class
Contribute actively	59,5	75,4
Work productively	52,1	85
Be responsible	69,3	88,6

Show flexibility and compromise	62,9	78,2
Respecting Others	74,3	88,6

Based on the results of the observation sheet analysis in Table 10, it shows that each indicator of collaboration skills in the experimental class obtained a higher average score than the control class.

Table 11. Observation Results of Communication Skills Indicators in the Control and Experimental Classes

Communication Skills Indicators	Average Score	
	Control Class	Experimental Class
Openness	67,1	81
Empathy	62,5	84,6
Supportive behavior	54,3	75,4
Positive behavior	71	85,5
Similarity	75,5	83,1

Based on the results of the observation sheet analysis in Table 11, it shows that each communication skill indicator in the experimental class obtained a higher average score than the control class.

Discussion

The results of this study indicate that the NHT cooperative learning model assisted by problem cards affects students' collaboration and communication skills. This is based on hypothesis analysis using the Independent Sample t-Test, which obtained a Sig. (2-tailed) value of 0.000 ($\alpha < 0.05$) for both skills, thus accepting the alternative hypothesis (H_a). Therefore, it can be concluded that there is a difference in students' collaboration and communication skills between the experimental class (using the NHT model assisted by problem card media) and the control class (using the discovery learning model).

The NHT learning model is a learning model that emphasizes student activity and trains them to interact with their peers and teachers (Iskandar & Leonard, 2019; Kusnadi & Kusumawati, 2020). This learning model can train students to be responsible, communicate effectively, and collaborate in problem solving (Manafe et al., 2022). The NHT learning model applied in this study was combined with problem cards, which were useful as tools to help students learn to collaborate, argue, and convey ideas. The problem cards were used as discussion material to focus students' attention on the material. This encouraged them to be more active in discussions and increased their interest in learning about the topics discussed.

The collaboration and communication skills of students in the experimental class using the NHT learning model, assisted by problem cards, obtained higher average scores than the control class. Based on the results of observations and questionnaires in the experimental class, both obtained higher average scores than the control class, as shown in Tables 2 and 3. This shows that the NHT learning model supported by problem cards can further optimize students' collaboration and communication skills. This is in line with the research by Tharihk et al. (2025), which explains that the NHT type of cooperative learning model is able to optimize

the collaboration skills of 10th-grade high school students. Nashiruddin et al. (2024) also stated that the NHT type of cooperative learning model is able to optimize the learning outcomes of Islamic Education and the communication skills of 12th-grade high school students.

The collaboration skill indicators analyzed based on the observation results in Table 10 show that the experimental class with the NHT learning model assisted by problem cards has good and very good categories. The collaboration skill indicators in the experimental class that are classified as very good are being responsible and respecting others, each with an average score of 88.6. Another indicator that is also classified as very good is working productively, with an average score of 85. The indicators of contributing actively and showing flexibility and compromise are classified as good, with average scores of 75.4 and 78.2, respectively.

The communication skills indicator, analyzed based on the observation results in Table 11, also shows that the experimental class with the NHT learning model assisted by problem cards has a good and excellent category. The communication skill indicators in the experimental class that were classified as excellent were openness with an average score of 81, empathy 84.6, positive behavior 85.5, and similarity 83.1. The indicators classified as good were supportive behavior with an average score of 75.4.

The results of field observations are consistent with these findings, namely that students are very good at exchanging opinions and accepting feedback during group discussions, reflecting indicators of openness and positive behavior. However, weaknesses are indicated by the lack of assistance from students in clarifying information conveyed by their peers, which is an indicator of supportive behavior. This condition may be influenced by various factors, such as a lack of insight, an inability to ask questions, shyness or fear of speaking, and a lack of time for discussion.

In line with the research by Anggraini and Nuraeni (2023), low student participation in expressing opinions during learning is caused by students' lack of courage to speak in public, distrust in the ideas they want to convey, and fear of negative responses from friends, such as being ignored or ridiculed. Anggraini and Nora (2024) also analyzed this phenomenon based on Vygotsky's theory, which indicates that the lack of student participation is caused by a lack of interaction and social support needed to bring them out of their comfort zone. However, the media-assisted NHT learning model using problem cards has been proven effective in optimizing students' communication skills, supported by the syntax in the model. The following is the NHT syntax that effectively optimizes students' collaboration and communication skills (Tharikh et al., 2025):

1. Numbering and questioning stages: Students are given numbers and equal opportunities to convey their discussion findings and perspectives on an issue. The numbering stage requires students to work productively according to the specified portions so that the collaborative discussion results are maximized (Yusup, 2021). In the questioning stage, students are encouraged to express their opinions based on their understanding through problem cards provided by the teacher.
2. In the head together stage, students discuss in groups to work on the problem cards given. This stage requires them to exchange ideas, give advice, and

decide on the right solution. This stage can optimize collaboration skills, particularly in terms of active contribution, flexibility, and compromise. This stage also optimizes students' communication skills, particularly in terms of openness, empathy, similarity, and positive behavior in expressing thoughts and understanding other perspectives.

3. Answering stage, students are randomly selected based on their ID numbers to present the results of their group discussions in front of the class (Khumaidah et al., 2023). This stage optimizes collaboration skills in terms of respecting others and being responsible. It also honors students' courage to speak in public, convey ideas clearly and structurally, and respond to questions. This stage trains students to be supportive of one another and to help clarify each other's answers.

The syntax of the NHT learning model effectively optimizes students' collaboration and communication skills through structured stages. The Numbering and Questioning stages ensure equal participation and responsibility, while encouraging students to express their perspectives. Furthermore, the Head Together stage encourages intensive discussion that instills active contribution, flexibility, compromise, openness, and empathy through the exchange of ideas and decision-making on appropriate solutions. The final Answering stage, with random calling, reinforces individual responsibility, hones the courage to speak, and trains students to convey ideas clearly and behave supportively in front of the class.

The use of problem cards in the NHT model also greatly supports the success of the research because it not only provides visual stimuli and relevant problems but also effectively facilitates the distribution of tasks and responsibilities among group members, so that each student can fully participate in the learning process (Yusriah, 2024). This media motivates students when faced with real-life problems, triggers focused discussions, and trains them to convey ideas in a structured manner. Thus, problem cards encourage more communicative and varied interactions, which is supported by the findings of Alfira and Izzah (2024) that this medium improves students' communication skills in constructing arguments and responding to questions, while also increasing student participation and engagement in discussions.

The discovery learning model implemented in the control class also encouraged group work to discover concepts, but its internal mechanism was not like NHT, which had to ensure that each group member contributed or understood equally. Collaboration may have occurred, but participation may not have been evenly distributed among members. The main focus of discovery learning was on the process of discovering concepts independently or in groups. Collaborative discussions may occur, but they are more about searching for information or experimenting, rather than building a deep shared understanding or agreeing on solutions as in the NHT model. This is consistent with the findings of Mukaramah et al. (2020), which explain that the discovery learning model is more efficient in developing conceptual understanding, but is less adequate in optimizing skills and emotions holistically.

Conclusion

The conclusion drawn from the findings and discussion is that there is an effect of the NHT cooperative learning model assisted by problem cards on

students' collaboration and communication skills in 10th-grade biology lessons at SMA Negeri 10 Semarang. This is evidenced by the results of the analysis of observation sheets and questionnaires on collaboration and communication skills, both of which show a Sig. (2-tailed) value of $0.000 < 0.05$. The syntax of the NHT learning model supports students' collaboration skills through the stages of numbering, questioning, and head together, while students' communication skills are supported by the stages of head together and answering.

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THE RELATIONSHIP BETWEEN READING HABITS AND STUDENTS' ACADEMIC ACHIEVEMENT IN THE DIGITAL ERA

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Received: 1 November 2025; Accepted: 25 November 2025

Abstract

The phenomenon of declining interest in traditional reading among students is seen, despite increasingly easy access to information through digital devices. The development of the digital era brings various conveniences in accessing information, but on the other hand, it poses challenges to students' reading habits, which in turn affect their academic achievement. Literature review is conducted. Several sources, such as journals, articles, and books relevant to the topic, are reviewed. A clearer understanding of the relationship between reading habits and students' academic achievement in the digital era is sought. The results indicate that reading habits contribute significantly to improving students' academic achievement. Previous studies indicate that educational success is influenced not only by cognitive abilities but also by sustainable literacy habits. The main obstacles identified include low regular reading habits, the influence of social media, and limited availability of reading materials. The correlation between reading interest and academic achievement is in the moderate category with a positive relationship. Educational success is not only determined by cognitive abilities but also by a consistent and high-quality literacy culture. Therefore, synergy between traditional and digital reading is an important strategy for building more effective learning patterns in the digital era.

Keywords: academic achievement, digital era, literacy culture, reading habits, student literacy

Introduction

Increasingly easy access to information through digital devices has changed people's reading patterns and habits, particularly among students. While reading was previously done through print media such as books, magazines, and newspapers, students now increasingly read on screens of devices, laptops, or tablets. This shift brings two opposing sides. On the one hand, advances in digital technology make it easier to obtain information and expand reading resources. However, on the other hand, this convenience also poses serious challenges to the quality of reading habits, which impacts students' academic achievement. In education, reading plays a vital role as the primary foundation for understanding and mastering various fields of knowledge. Reading not only functions as a cognitive process but also serves as a starting point for developing critical, creative, and reflective thinking skills in students. Raising students' awareness of reading diligently to broaden their knowledge is a crucial step in developing and optimizing



their potential. Therefore, reading is a crucial part of the learning process, as it supports language development, thinking skills, and academic achievement. Research by Amri and Rochmah (2021) shows that reading literacy skills significantly correlate with student achievement. This demonstrates that reading is not only a learning tool but also an essential element that can impact the overall quality of education.

Academic achievement reflects the level of student achievement in meeting learning objectives in each subject. Grades obtained, whether in the form of letters or numbers, reflect student learning outcomes (Arikunto, 2015). One factor influencing academic achievement is reading interest. Without a strong interest, reading is often seen as an obligation, rather than a pleasurable necessity. In the digital era, reading habits face new challenges due to technological advances and the rise of social media. Students are now more interested in short, visual content than in reading long texts that require concentration and in-depth analysis. This instant reading pattern risks reducing critical thinking skills and in-depth comprehension. Therefore, the role of teachers, parents, and schools is crucial in re-cultivating a reading culture that balances print and digital media. As stated by Fajar et al. (2022), low reading interest, limited access to quality reading materials, and weak environmental support are major obstacles to strengthening literacy. Therefore, reading habits remain a crucial foundation for improving academic achievement. Technology should be used as a means to enrich the learning process, not replace it, so that students can think critically, reflect, and excel in the digital age.

The purpose of this paper is to understand the relationship between reading habits and student academic achievement in the digital age. Through this paper, it is hoped to determine the extent to which the intensity and type of reading materials, both printed and digital, influence student learning outcomes. Furthermore, this study also aims to explore how changes in reading patterns due to technological developments affect student motivation and learning styles. Thus, this study focuses not only on reading as an academic activity but also as a process that fosters awareness, discipline, and intellectual sensitivity in facing the challenges of the modern era.

Method

This paper employed a literature review with a qualitative descriptive approach. Data sources for this study were obtained from journals and scientific articles discussing reading habits, academic achievement, and literacy dynamics in the digital age. Data were collected through a literature search using Google as a search engine with the keywords: “reading habits”, “academic achievement”, “digital literacy”, and “students.” Analysis was conducted by grouping the data based on the literature search results, namely by key emerging themes, such as the relationship between reading habits and academic achievement, factors influencing student reading habits, and the impact of digital technology developments on reading patterns. Each piece of literature obtained was then analyzed to identify similarities in ideas, differences in perspectives, and the direction of previous research findings. Furthermore, data validation was conducted through cross-referenced sources and an assessment of the credibility of the literature to ensure the validity and relevance of the information used in compiling the paper.

Findings and Discussion

Reading habits are a key pillar of the educational process, both in formal school contexts and in daily life outside the classroom. Reading not only serves as a means of acquiring information but also plays a crucial role in shaping students' mindsets, attitudes, and character. Through regular reading, students can develop cognitive abilities, broaden their horizons, and foster sensitivity to moral and social values. Therefore, reading habits play a crucial role in supporting academic success and character development in the modern era, which is rife with digital challenges. Research by Amri and Rochmah (2021) supports this view by demonstrating a positive relationship between reading literacy skills and elementary school students' academic achievement. Students with high levels of reading literacy tend to achieve more optimal learning outcomes because they are able to understand subject matter deeply and critically. However, the study also revealed that the correlation between reading literacy skills and academic achievement was only 23.2%, with an effective effect of 5.4%. This shows that although reading literacy influences academic achievement, many other factors contribute to student learning outcomes, such as motivation, social environment, and family and school support. Regular reading can improve critical thinking, logic, and reading comprehension, ultimately improving learning outcomes. Meanwhile, research by Aulia and Megawanti (2024) found that study habits, including reading, significantly contribute to improving literacy skills in the Minimum Competency Assessment (AKM). Students who enjoy reading have been shown to excel in understanding test instructions, interpreting texts, and drawing logical conclusions, both in Indonesian and other subjects such as Mathematics, Science, and Social Studies. Thus, reading serves as a fundamental foundation that supports the entire learning process in schools.

Literacy culture among students is both a crucial issue and a major challenge in the digital era. Low reading interest in Indonesia remains a serious concern, particularly among secondary school students. Studies, such as the one conducted by Rizal et al. (2024), show that implementing a literacy culture has a positive and significant impact on student achievement. Literacy activities in schools foster reading habits, enrich their knowledge, and provide essential provisions for students to continue to higher education. The higher a student's literacy level, the greater their chances of achieving satisfactory academic performance.

According to Ernalis et al. (2018), reading culture or literacy is a person's ability to understand text and process its meaning to apply it in everyday life. Learning to read not only trains the ability to understand written messages but also hones analytical thinking skills as students learn to connect new knowledge with information they already have. This view is in line with the opinion of Mualimah and Usmaedi (2018), who emphasized that reading plays a crucial role in improving thinking skills, deepening knowledge, and keeping up with scientific developments. The higher a student's interest in reading, the greater their reading intensity, which has implications for improving mastery of subject matter and learning outcomes.

Previous studies suggest a strong correlation between reading habits and student academic achievement. Students who regularly read textbooks and other reading materials have a better understanding of the material taught, enabling them to apply their knowledge in exams and schoolwork. Reading habits also improve language skills, strengthen concentration, and foster self-discipline. Furthermore, regular reading activities can broaden students' perspectives and foster curiosity

about new things. According to Mutadin et al. (2024), four main elements influence students' interest in reading: the availability of reading facilities, the role of teachers, parental support, and teaching methods. First, the availability of facilities such as a well-stocked library and comfortable reading areas can foster students' enthusiasm for reading. Second, teachers play a strategic role in instilling reading habits through interactive and engaging learning activities. Teachers who actively encourage students to read and assign literacy-based assignments can foster a sustained interest in reading. Third, parental support is also a crucial factor. Parents who provide reading materials at home and accompany their children while reading can increase student motivation and discipline.

Meanwhile, according to Ananda and Efendi (2024), students' reading interest is also influenced by other factors such as lack of access to interesting reading materials, a weak literacy culture at home and in the community, and increasing dependence on technology and social media. In today's digital era, many students prefer to spend time with gadgets rather than reading books. This leads to reduced reading time and decreased concentration. Furthermore, less innovative teaching methods in schools can also make reading activities feel boring and irrelevant for students. A supportive social environment, such as peers who enjoy reading and inspiring teachers, can form positive reading habits. However, technological advances are often a double-edged sword. On the one hand, technology facilitates access to digital reading materials such as e-books and online articles. On the other hand, excessive use of gadgets for entertainment actually shifts interest in reading conventionally. Although e-books are increasingly popular, printed books still have their own value in building focus and perseverance in in-depth reading.

In the context of modern education, reading habits are inseparable from information literacy skills, a 21st-century competency. Literacy is no longer simply defined as the ability to read written texts, but also encompasses the ability to understand, interpret, and evaluate various forms of information available in digital media. Students who habitually read both print and digital media will develop sharper critical thinking skills, be able to sort valid information from misleading, and connect various sources of knowledge logically and contextually. Therefore, reading habits are a key asset for navigating the rapid flow of information in the digital era, which is often instantaneous and superficial.

In the digital era, reading habits have undergone a major transformation. While previously students primarily read textbooks or printed magazines, reading resources have now shifted to digital media such as online articles, electronic journals, e-books, and informative social media. This phenomenon has had two contradictory impacts. On the one hand, technology opens up broad access to sources of knowledge without the constraints of space and time. Students can easily download books, read scientific articles, or participate in online academic discussion forums. However, on the other hand, this ease of access also comes with challenges in the form of distractions from non-educational content such as entertainment, online games, and social media. Besides distraction, another challenge that arises in digital reading culture is superficial reading, which involves reading quickly and superficially. Many students are accustomed to skimming or scanning without truly understanding the text's meaning. This results in poor critical thinking skills and conceptual understanding of the subject matter. The habit of instant digital reading and page-hopping can reduce the brain's capacity to maintain

focus and analyze information in depth. Therefore, developing a structured and reflective reading habit remains necessary so students can balance reading speed and depth of understanding (Bresó et al., 2022).

In addition to support from schools and families, digital media can also be used productively to strengthen a reading culture. Digital platforms such as online library applications, educational blogs, and literacy channels on social media can be engaging ways for students to expand their knowledge. However, guidance is needed in selecting quality reading sources to prevent students from falling prey to invalid or hoax information. Therefore, strengthening a reading culture is not solely the responsibility of language teachers, but the responsibility of all stakeholders in education. The government needs to expand access to quality reading materials, improve digital literacy training for teachers, and encourage collaboration between schools, libraries, and literacy communities. Furthermore, students need to be equipped with the skills to select reading materials that suit their learning needs. A daily reading habit, both in print and digital formats, can be incorporated into a curriculum that strengthens the Pancasila student profile, emphasizing independence, critical thinking, and scientific reasoning.

In addition to various studies demonstrating the influence of reading habits on academic achievement, it is also important to understand how these habits are formed and maintained amidst the current wave of educational modernization. The formation of reading habits is not an instant process, but rather the result of long-term habituation influenced by the social environment, school culture, and students' intrinsic motivation. Environments rich in reading and rewarding reading activities tend to produce students with high literacy levels. On the other hand, schools that do not provide space for reflective reading activities often lead students to read only for assignments, rather than for intellectual needs. Furthermore, teacher intervention also has a significant influence on fostering a reading culture. Teachers are not only transmitters of subject matter but also role models for active readers. Teachers who demonstrate enthusiasm for reading and share their literacy experiences with students may foster higher reading motivation. Literacy-based learning, such as Reading Journals, Book Talks, and Reading Circles, has been proven to increase reading interest and text comprehension. In the context of digital-era learning, teachers can also combine technology with reading activities, for example, through the use of e-books, interactive literacy applications, and online platforms like Google Classroom for reading reflection activities.

However, it is important to recognize that challenges to reading habits come not only from technological distractions but also from changes in the learning styles of the younger generation. Generations Z and Alpha, born and raised in a digital ecosystem, have different learning characteristics from previous generations. They tend to prefer information that is visual, interactive, and fast. If not balanced with the habit of reading long and reflective texts, this tendency can weaken analytical skills and reading retention. The government also has a strategic role in strengthening the national literacy ecosystem. Providing dedicated funding for the development of school digital libraries, providing digital literacy training for educators, and providing local reading materials relevant to students' lives are concrete steps that can increase reading interest. Furthermore, synergy between the Ministry of Education, literacy communities, and media institutions can expand the

reading movement into the public sphere. Overall, reading in the digital age is not merely an academic activity but also an integral part of national character building.

Amidst the rapid flow of information and instant culture, the ability to read critically, reflectively, and sustainably is a key determinant of the quality of Indonesia's young generation. Reading is not only about understanding texts, but also about building awareness, fostering empathy, and sharpening reasoning skills. Therefore, strengthening a reading culture needs to be a shared priority so that Indonesian students are not only academically intelligent but also wise in filtering and managing information in this fast-paced and complex digital world. Furthermore, it is important to understand that reading habits in the digital era cannot be separated from the social and cultural context of society. Rapidly changing lifestyles demand a new approach to fostering reading interest among students. Schools need to create a fun literacy ecosystem, oriented not only toward assignments or grades, but also toward an appreciation of reading as part of intellectual needs. Activities such as book clubs, digital reading corners, book review competitions, or "one week, one reading" programs can foster a love of reading. Furthermore, the use of literacy-based digital platforms such as Wattpad, Google Books, and the National Library Digital can provide interactive and contextual learning media. Student involvement in digital literacy projects can also encourage them to play an active role as readers and creators of literacy content. With teacher support and a conducive environment, reading habits not only contribute to academic achievement but also foster independence, curiosity, and critical thinking skills, which are essential tools for Indonesia's young generation in facing the challenges of globalization and the industrial revolution.

Conclusion

Based on the discussion above, it can be concluded that there is a strong relationship between reading habits and student academic achievement in the digital age. Students who have a regular reading habit have been shown to be better able to understand course material, think critically, and have better analytical skills than students with low reading interest. Reading habits also help students develop information literacy, namely the ability to understand, select, and process various sources of knowledge amidst the rapid digital flow. However, the digital age presents new challenges in the form of social media distractions, decreased focus, and the emergence of a tendency towards superficial reading. Therefore, an educational strategy is needed that balances the use of technology with the development of reflective and in-depth reading habits. Teachers, parents, and educational institutions play a crucial role in fostering a culture of literacy that adapts to technological developments. Consistently developing reading habits will improve students' academic achievement not only quantitatively but also cognitively and character-wise. Therefore, reading is key to producing a literate generation that is intelligent, critical, and ready to compete in the digital age. Therefore, it is recommended that schools continue to strengthen literacy programs through daily reading activities and the use of educational digital media. Parents should participate in creating a home environment conducive to reading, while the government is expected to support this by providing digital literacy facilities and modern libraries. With the synergy of all parties, reading habits can develop into a

sustainable learning culture and become a key foundation for the success of national education in the future.

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THE EFFECT OF THE SOPLE LEARNING MODEL ON STUDENTS' LEARNING OUTCOMES IN THE TOPIC OF ENVIRONMENTAL CHANGE AND CONSERVATION

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Received: 18 November 2025; Accepted: 30 November 2025

Abstract

The purpose of this study is to investigate how students' learning results in the area of environmental change and conservation are impacted by the SOPLE (Self-Study, Opening, Practice, Listening, Evaluation) learning paradigm. The Flipped Classroom and the SAVI approach (Somatic, Auditory, Visualization, Intellectually) are combined in the SOPLE model to promote engaging and meaningful learning. There was a nonequivalent control group in a quasi-experimental design. Class XA was the regular group at St. Maria Iteng Private Senior High School, Manggarai, NTT, taught using traditional techniques, while Class XB was designated as the experimental group, taught using SOPLE. Multiple-choice pretest and posttest items made up the research instruments. The posttest difference between the experimental and regular groups was shown to be statistically significant by the Mann-Whitney U test ($U = 34.000$, $Z = -4.017$, $p < 0.001$). With a large effect size ($r = 0.68$), the experimental class's mean rank (25.00) was greater than the regular class (11.39). These results suggest that the SOPLE model works to enhance biology learning outcomes for students, especially when it comes to environmental subjects.

Keywords: environmental change and conservation, flipped Classroom, learning outcomes, quasi-experimental design, SAVI, SOPLE

Introduction

The learning model is the most important element in the learning process in the classroom. According to Ristanti et al. (2019), learning models can influence students' engagement and level of understanding of learning material in biology. In Novitayani's (2016) research, engaging and appropriate learning models can increase students' motivation and attention during class. One engaging and appropriate learning model for students is SAVI (Somatic, Auditory, Visual, Intelligence).

SAVI is a learning model that maximizes students' various senses so that students can learn more effectively and efficiently in a classroom setting. Ristanti et al. (2019) conducted research demonstrating that the SAVI-based learning model



was highly effective, significantly improving the activeness and understanding of students in Class X MIA 1 SMAN 1 Papar concerning ecosystem material, with an effectiveness level reaching 81.9%. This percentage falls within the very positive criteria, indicating that the learning model is appropriate and engaging for increasing student engagement and understanding of the ecosystems material.

Another effective learning model is the flipped classroom. Scientific studies show that implementing a flipped classroom in a Chinese secondary school can improve student learning outcomes and motivation (Hung et al., 2019). This finding aligns with research conducted by Bhagat et al. (2016), which revealed that the use of flipped classrooms in Taiwan can improve student motivation and learning achievement.

Flipped Classroom is a learning model that encourages students to study material independently at home according to assignments given by the teacher. Thus, class time can be used for discussion, Q&A, and in-depth study of the material (Ministry of Education and Culture, 2020). According to Zainuddin et al. (2019), the use of the flipped classroom has several advantages, including: (1) increasing student learning motivation, (2) encouraging active student involvement in the learning process, (3) improving academic achievement, and (4) developing independent learning skills in students.

The SOPLE learning model is an innovative learning model that combines the SAVI and Flipped Classroom learning models. The SOPLE learning model was first developed by Widyaningsih (2024), a senior researcher in the Biology Education Study Program at Sanata Dharma University, Yogyakarta. The title of Widyaningsih's research is "Development of the SOPLE Learning Model on Human Mobility Material." The researcher is interested in implementing the SOPLE learning model created by Widyaningsih in grade X.

The combination of elements from the two models (SAVI and Flipped classroom) produces a new syntax that is reflected in the stages of learning activities in the teaching module. The syntax of the SOPLE learning model includes Self Study, Opening, Practice, Listening, and Evaluation. While undergoing teaching assistance at SMAS St. Maria Iteng, Manggarai, NTT from February - June 2025, the researcher was interested in specifically examining the learning outcomes of students in grade X with the application of the SOPLE learning model on the material of environmental change and conservation for grade X. This material was chosen because it is very contextual, can encourage students to make concrete contributions to the environment, mother earth and is the last material in the series of materials in this semester.

The novelty of this study lies in its critical transition from the model development stage to its practical, real-world implementation. Previous research by Widyaningsih (2024) completed the Research and Development (R&D) phase of the SOPLE learning model, yielding a highly validated model and learning tools (expert validation score: 0.88). However, the work was confined to development, and Widyaningsih (2024) did not proceed to the actual implementation or effectiveness testing in a classroom setting. This creates a critical research gap regarding the practical utility of the SOPLE model in diverse educational environments. This thesis directly addresses this gap by executing the first known field implementation of the validated SOPLE model to empirically test its efficacy.

This implementation provides novelty through a highly specific and rigorous framework. This research constitutes the first application of the SOPLE model within the context of the Merdeka Curriculum, applying it to the distinct subject matter of environmental change and conservation for Grade X students at a unique regional setting (St. Maria Iteng Private Senior High School, Manggarai, NTT). Furthermore, a rigorous methodological combination is employed for the effectiveness analysis, which includes the calculation of descriptive statistics, Normalized Gain (N-Gain), Normality and Homogeneity Tests, and the use of non-parametric statistical testing (e.g., Mann-Whitney U test) to determine statistical significance and effect size. Consequently, this work is not a mere contextual replication but a pioneering study that provides robust evidence of the SOPLE model's effectiveness in a contemporary Indonesian educational setting, utilizing a precise analytical lens previously unexplored by the model's developers.

The topic of Environmental Change and Conservation is certainly significant in the biology curriculum because it provides students with an understanding of the interrelationship between humans and their environment. This material leads students to understand the impact of human activities on ecosystems and the urgency of maintaining environmental balance (Mardin et al., 2024).

In reality, in the 10th grade of St. Maria Iteng Private Senior High School, student learning outcomes on this topic are still relatively low. This is due to the lack of varied teaching methods and a lack of student engagement in the learning process. Students tend to be passive and unmotivated to understand the concepts presented. As a result, learning outcomes are suboptimal, and students' understanding of the importance of environmental conservation remains low.

Seeing the importance of this material and the problems of student learning outcomes, innovation is needed in learning models that are more effective and appropriate to student needs. Interactive learning models and actively involving students in the learning process can increase student motivation and understanding. Therefore, the application of the SOPLE learning model, which is a combination of SAVI and flipped classroom, is expected to be able to answer this challenge and improve student learning outcomes in the material of Environmental Change and Conservation. *The purpose* of this study was to determine the effect of the application of the SOPLE learning model on student learning outcomes in the material of Environmental Change and Conservation in grade 10.

The SOPLE (Student-Oriented Project-based Learning in Environmental Education) model is structurally rooted in several established learning theories to maximize student engagement and effectiveness. Instead of applying a single paradigm, SOPLE integrates concepts from Social Constructivism, Multiple Intelligences, Accelerated Learning, and Holistic Education to create a comprehensive learning environment.

1. Social Constructivism

The SOPLE model aligns with Social Constructivism (Piaget & Vygotsky) by viewing learning as an active process where students construct their own knowledge through experience (Suryana et al., 2022; Nerita et al., 2023). Integration with SOPLE: This theory is primarily realized in the Self-Study (S) and Practice (P) stages, where students engage in dialogue, trial-and-error, and collaborative project work to form shared understanding and practical skills.

2. Theory of Multiple Intelligences

The model acknowledges Howard Gardner's premise that every individual possesses various types of intelligence (linguistic, logical-mathematical, naturalist, etc.) that develop differently (Berliana & Atikah, 2023; Jaya et al., 2023). Integration with SOPLE: The Practice (P) stage (project execution) and the Evaluation (E) stage (reporting/presentation) are deliberately designed to cater to diverse intelligences. Projects allow students to express learning through visual (spatial), verbal (linguistic), or experimental (naturalist/kinesthetic) means, ensuring broader engagement.

3. Accelerated Learning Theory

Drawing on the principles proposed by Dave Meier, SOPLE incorporates Accelerated Learning to optimize learning design and effectiveness by emphasizing that learning involves the whole mind and body, is creative, and benefits from cooperation (Zuhara & Busriadi, 2023; Rahmiati & Neviyarni, 2021). Integration with SOPLE: The Opening (O) stage focuses on creating a positive emotional state and a conducive learning environment (Meier's principle of positive emotion), while the Practice (P) stage emphasizes cooperative, hands-on activity, accelerating learning through active doing rather than passive reception.

4. Holistic Education Theory

SOPLE embraces the concept of Holistic Education, which seeks to harmoniously integrate the intellectual, emotional, social, and spiritual aspects of development (Pong, 2021). This approach, often rooted in social constructivism, focuses on educating the whole child (Miseliunaite et al., 2022). Integration with SOPLE: The Listening (L) stage and the Evaluation (E) stage specifically address the holistic dimension. The Listening (L) stage encourages introspection and reflection (intrapersonal/spiritual aspect), while the collaborative Practice (P) stage fosters the social dimension, ensuring development extends beyond mere intellectual potential.

SAVI learning model

Student learning outcomes are greatly influenced by the learning process at school, particularly emotional factors. Learning models are key to creating an active, enjoyable, and meaningful learning process, so they need to be identified, implemented, and developed optimally (Tibahary & Muliana, 2018; Mawikere, 2022). Rusman (2016) stated that one of the innovative learning models is SAVI. (Somatic, Auditory, Visualization, Intellectually), which involves all the senses and emotions in the learning process. This model consists of somatic, which is learning through movement and practice; auditory, through listening and speaking; visual, through observation and illustration; and intellectual, which focuses on problem-solving and explanation. This approach is expected to improve student understanding, resulting in better learning outcomes and the attainment of the required Minimum Mastery Criterion (MMC). The steps of the SAVI model learning activities, according to Purba and Sarmita (2022), can be described as follows.

Table 1. Steps in SAVI Model Learning Activities

Stages	Teacher Activities
Preparation	Students prepare themselves for the learning process guided by the following teacher-designed activities: - Apperception and listening to the learning objectives (Auditory) - Students enter their respective groups (Somatic) - Students build interest, motivation, and curiosity (Auditory)
Delivery	Students actively discover the learning material and construct their own knowledge, involving and facilitated by the teacher through the following steps: - Students receive the material along with concrete examples (Somatic and Auditory). - Students receive a detailed explanation of the material from the teacher based on the provided examples (Auditory).
Training	At this stage, students integrate and assimilate new knowledge and skills through various means, such as: - Students work on the worksheets by engaging in group discussions (Visual and Intellectual). - Students present the results of their work and practice listening to other students when providing responses and asking questions (Somatic, Auditory, Visual, Intellectual). - Students receive teacher assessment regarding the results of their work and make corrections if any errors are found (Auditory).
Appearance	This stage aims to assist students in applying and developing new knowledge and skills through the following activities: - Students complete an evaluation in the form of a question sheet, which is used to assess and enhance their understanding and skills after the learning process (Somatic and Intellectual). - Students review the material that has been previously taught together with the teacher; subsequently, students draw conclusions and receive assignments for the next session (Auditory).

In Hartati (2023), the SAVI learning model (Somatic, Auditory, Visual, Intellectually) has several advantages, one of which is its ability to develop students' intelligence comprehensively. This is due to the integration of various learning aspects, such as physical movement combined with activities that stimulate intelligence. The SAVI learning model has several weaknesses, one of which is the need for adequate facilities and infrastructure for optimal learning. This necessitates a substantial investment in educational costs to provide facilities appropriate to the model's needs (Sutarna, 2018). The SAVI learning model can pose a challenge to developing independence and critical thinking skills in students (Natasha et al., 2024).

Flipped Classroom Learning Model

According to Rakhmawati and Choiriyah (2023), Flipped Classroom is a learning method that reverses the traditional learning process. In this model, students first study the material at home, then complete assignments and discuss them in class. This contrasts with the traditional method, where learning takes place in class and assignments are completed at home. This allows for more effective use of class time for discussion and Q&A. Furthermore, this model is more flexible because it can adapt to the diverse abilities, backgrounds, and characteristics of students (Patandean & Indrajit, 2020). The flipped classroom learning model can

be used effectively as a learning strategy that utilizes online resources (Wells & Holland, 2016). Rafiqah and Dani (2021) outline the steps for the Flipped Classroom model's learning activities:

Table 2. Steps in the Learning Model Activity of Flipped Classroom

Stages	Teacher Activities
Preparation (Pre-class)	
Activities in Class	- At this stage, students receive guidance from the teacher throughout the learning process. - Students are divided into several groups, with each group consisting of 4–5 members. - The material previously viewed by the students is discussed through group discussions and a question-and-answer session. - Students interact (through questions and answers) with the teacher to reinforce the concepts of the material being studied. - Students receive guidance and assistance in problem-solving through Student Worksheets (SWS). - Students collaborate within their groups to solve the given problems. - The teacher facilitates the students to express their ideas and concepts related to the given problems. - One student group presents the results of the discussion while the other groups provide responses.
Follow-up	- Students receive a teacher assessment to evaluate their understanding of the learning material. - Students receive assignments and material for the next session.

Flipped classroom has several advantages. This model allows students to learn at their own pace, giving them the opportunity to review material they don't yet understand. Homework can be completed in class, allowing students to directly ask the teacher if there are any unclear parts (Kurniawati et al., 2019). The Flipped Classroom model allows students to access learning materials more effectively, while class time can be used more productively for discussion and interaction. Research also shows that teachers who implement this model tend to achieve better outcomes than those using conventional learning methods.

However, according to Talbert, there are several shortcomings in the implementation. One of these is creating instructional videos, which takes a lot of time and effort for teachers. Furthermore, if teachers cannot actively interact with students during online learning, this can reduce students' motivation to learn. This model can also be a challenge for students accustomed to traditional learning, who may struggle to adapt to the new approach. Some students may also struggle to understand material presented through videos created by the teacher themselves (Kurniawati et al., 2019). Students who don't have a cell phone, laptop, or computer will have difficulty accessing materials or videos provided by the teacher. Difficult internet access can also limit students' ability to understand the material or video content being delivered (Rafiqah & Dani, 2021).

SOPLE Learning Model

The SOPLE learning model is a combination of two learning models, namely SAVI (Somatic, Auditory, Visualization, Intellectually) and flipped classroom. The combination of these two models creates a new syntax consisting of five main steps:

Self Study, Opening, Practice, Listening, and Evaluation. This model emphasizes student-centered learning, with the teacher acting as a facilitator supporting the learning process. The uniqueness of this model lies in its ability to accommodate five of the eight types of human intelligence: linguistic, logical-mathematical, kinesthetic, interpersonal, and naturalist. This model is applied to topics related to environmental change and preservation (Widyaningsih, 2024).

The SAVI learning model emphasizes the full use of students' senses through various activities: physical activities (Somatic), speaking and listening (Auditory), observation and description (Visual), and problem-solving and critical thinking (Intellectual). By fully utilizing the senses, it is hoped that this will stimulate students' enthusiasm and interest in participating in the learning process, so that learning can proceed optimally. Meanwhile, the learning model SOPLE integrates in-class learning with out-of-class learning. The goal is to maximize learning activities. Students can study the material from the teacher at home, and it is hoped that they will be better prepared to learn in class.

The SOPLE learning model aims to motivate students to participate in the learning process while also enabling teachers to effectively deliver material with a broad scope and complex content (Widyaningsih, 2024). The following are the steps in SOPLE.

Table 3. Steps of the SOPLE learning model

Stages	Teacher Activities
Self-Study	- Students receive the learning material via a WhatsApp group or a learning platform. - Students create a summary of the shared material.
Opening	- Students receive apperception that stimulates interest, motivation, and curiosity (Auditory). - Students listen to the learning objectives (Auditory). Students are divided into several groups (Somatic).
Practice	- Under the teacher's guidance, students complete the student worksheets by engaging in group discussions (Visual and Intellectual). - Students present the results of their work with their group members, and other students respond to the work and assess the results. Other students also have the opportunity to ask questions (Somatic, Auditory, Visual, Intellectual). - Students attend to the teacher's assessment of their work results and correct the answers if any errors are found (Auditory).
Listening	- Students listen to the teacher when clarification is provided regarding any errors in the students' work results (Auditory). - Students attend to the teacher's affirmation of the material that has been studied, detailing it based on real-world examples (Auditory and Visual).
Evaluation	- Students complete a learning evaluation in the form of questions to determine their level of understanding and skills (Intellectual). - Students draw conclusions and receive assignments for the next session (Auditory and Intellectual).

The SOPLE model has several advantages, including combining various types of student intelligence, introducing more engaging and interactive learning methods, and increasing student motivation. Teachers can be more effective in teaching complex material because this method provides opportunities for students

to learn outside of class and discuss the material in class (Widyaningsih, 2024). Widyaningsih further stated that while this model is effective, its implementation requires adequate facilities, such as access to technology that supports independent learning outside of the classroom. Furthermore, students accustomed to traditional learning may face challenges adjusting to this model.

Method

This research was conducted using a quasi-experimental approach. This approach was chosen because it was not possible to randomly assign subjects to the experimental and regular classes (control). The research design used was a Nonequivalent Control Group Design. This research design involved two non-randomly selected groups, where one group was given treatment (the SOPLE learning model) and the other group was not (conventional learning).

The study was conducted from February 9, 2025, to June 10, 2025. The study was conducted at St. Maria Iteng Private High School, Satarmese District, Manggarai Regency, NTT Province. The population in this study was all students in grades XA and XB at St. Maria Iteng Private Senior High School. Class XA consisted of 29 students and Class XB consisted of 28 students.

All 29 students in Class XA and 28 students in Class XB at St. Maria Iteng Private Senior High School made up the initial group for this study. However, there were three main methodological reasons why the final studied sample was smaller. First, a number of students were eliminated because they did not finish the pretest and posttest (missing data). Second, the decrease was also influenced by student absences during the testing times. Due to these exclusions, the learning outcome population was decreased to a final sample size of 35 students for the primary analysis, with 17 students in Class XB and 18 students in Class XA.

Tests were used as the data collection techniques. In this study, data on the learning outcomes of tenth-grade students were collected through pretests and posttests. These tests aimed to measure students' understanding of environmental change and conservation, as outlined in the Independent Curriculum (*Kurikulum Merdeka*) teaching module. Daily tests (posttests) were also used to monitor students' learning progress as a summative assessment. Furthermore, the implementation of Student Worksheets (LKPD) served as a formative assessment, facilitating the application of students' knowledge and skills, and providing data on their competency achievement.

The quality testing of the posttest instrument, which consisted of 36 items, was conducted to ensure the instrument possessed adequate psychometric quality, focusing equally on validity, reliability, discrimination index, and difficulty level. The item analysis began with validity, categorized as low (0.200 - 0.399), adequate (0.400 - 0.599), high (0.600 - 0.800), and very high (0.800 - 1.00). The results indicated that 18 items were valid and 18 items were not. The valid items predominantly fell into the high criterion (12 items) and the adequate criterion (6 items). Subsequently, the overall instrument reliability, measured using Cronbach's Alpha, was determined. The quality criteria for reliability range from very low (0.000 - 0.200) to very high (0.801 - 1.00). The obtained value was 0.732, which classifies the instrument's reliability as high (0.601 - 0.800), suggesting good internal consistency across the items.

Furthermore, analysis of item characteristics involved the discrimination index and the difficulty level. The discrimination index was grouped into poor (< 0.19), adequate ($0.20 - 0.29$), good ($0.30 - 0.39$), and very good (> 0.40). The item distribution showed 23 items rated as very good, 8 items as adequate, and 5 items as poor. Simultaneously, the item difficulty was evaluated based on the criteria of difficult ($0.00 - 0.30$), moderate ($0.31 - 0.70$), and easy ($0.71 - 1.00$), revealing that 22 items were classified as moderate and 14 items as easy.

Based on the synthesis of all four critical quality factors, the items deemed acceptable and selected for the final score calculation were those that met the validity criterion, possessed a moderate difficulty level ($0.31 - 0.70$), and exhibited an adequate discrimination index or higher (score > 0.20). Following a rigorous selection process, a total of 18 best items were finalized from the initial 36 items for inclusion in the final score calculation, ensuring the instrument used is aligned with the learning objectives and possesses optimal psychometric quality across all crucial measurement aspects.

Student Learning Outcome Data Analysis is analyzed using the following steps.

1. Descriptive Analysis.

Student learning outcomes are seen from the average value, minimum value, maximum value, standard deviation, and percentage of learning completion. Individual completion is measured by the Minimum Standard for Completion 70, and the student's learning outcome score is calculated using the following formula (Astuti, 2023).

$$\text{Student Learning Outcomes Score} = \frac{\text{Correct Answers score}}{\text{Total score}} \times 100\%$$

Students are categorized as having completed a course if they receive a score above 70; scores below 70 are considered incomplete. The following is the formula for class completion percentage (Astuti, 2023).

$$\text{Class completion rate} = \frac{\text{Number of completed students}}{\text{Total student participants}} \times 100\%$$

Categorizing student learning outcomes typically refers to assessment categories on a scale of 0–100. Descriptive analysis also describes student learning outcomes by examining the mean, median, minimum, maximum, and standard deviation. Before conducting statistical tests, it is crucial to examine the underlying pattern.

2. Normalized Gain (N-Gain) Student Learning Outcomes

The N-Gain formula is used to find out how much learning outcomes have improved from pretest to posttest. The high N-Gain value in the experimental class compared to the regular class (control) provides information that the treatment is effective in improving learning outcomes.

3. Normality Test of Student Learning Outcomes

The normality test of learning outcomes is useful for determining whether the learning outcome data is normally distributed. The normality test is needed to determine whether the data follows a normal distribution because the learning outcomes are in the form of scores (interval/ratio scale). In addition to using the Shapiro-Wilk, this study also used Kolmogorov Smirnov.

4. Homogeneity Test of Student Learning Outcomes

Homogeneity test of student learning outcomes is carried out to determine whether the variance in the experimental class and the regular class (control) is homogeneous or not, and also to ensure whether the variance between the experimental and regular class (control) is homogeneous. Levene's test is usually used to test homogeneity.

5. Hypothesis Testing of Student Learning Outcomes

The hypothesis test aims to determine whether there is a significant difference in learning outcomes—specifically at the posttest stage—between the experimental class using the SOPLE model and the regular class (control) utilizing the conventional method. The independent sample t-test is used if the data is normally distributed and homogeneous, and the non-parametric Mann-Whitney U test is used if the data is not normally distributed. The hypothesis of student learning outcomes, namely: a) H_0 (Null hypothesis): There is no significant difference in posttest learning outcomes between students taught with SOPLE and those taught conventionally on the material Environmental Change and Conservation in class X St. Maria Iteng Private Senior High School, Manggarai, NTT. b) H_a (Alternative hypothesis): There is a significant difference in posttest learning outcomes on the material of Environmental Change and Conservation in class X St. Maria Iteng Private Senior High School, Manggarai, NTT.

Findings and Discussion

Descriptive Analysis of Student Learning Outcomes

Descriptive analysis shows a general overview of the distribution of student learning outcomes in the experimental and regular class (control) before and after treatment (pretest) and after treatment (posttest). The descriptive analysis shows the number of students (N), average value (mean), median, mode, standard deviation, variance, range, minimum value, and maximum value. The data are presented in Table 4 below.

Table 4. Descriptive Data on Student Learning Outcomes

	N	Minimum	Maximum	Sum	Mean	Std. Error	Std. Deviation	Varian
Experiment Pretest	17	14	93	1024	60,24	4,87	20,08	403,19
Experiment Posttest	17	56	100	1577	92,76	3,07	12,66	160,31
Regular Pretest	18	43	82	1247	69,28	2,60	11,03	121,85
Regular Posttest	18	63	83	1350	75,00	1,54	6,57	43,17

Based on Table 4, we can see an increase in learning outcomes in both classes from the pretest to the posttest. In the experimental class, the average score increased from 60.24 to 92.76 after the implementation of the SOPLE learning model. The median score also increased from 68.00 to 100.00, and the mode from 71 to 100. These increases indicate that most students achieved high scores on the posttest. The maximum score increased to 100, while the minimum score also increased from 14 to 56. Although the standard deviation decreased slightly from 20.08 to 12.66, this still shows a more even distribution of scores towards high scores after the treatment (implementation of the SOPLE learning model).

In the regular class (control), the average score also increased from 69.28 to 75.00, but not as much as in the experimental class. The median increased from 73.00 to 78.00, and the mode remained stable at 78. The minimum score increased from 43 to 61, and the maximum score increased gradually from 82 to 83. The standard deviation decreased significantly from 11.04 to 6.57, indicating that the distribution of scores became more even after conventional learning. Overall, when compared to the conventional class, the experimental class achieved better and more widespread learning to high scores. The data in Tables 5 and 6 below are the categorization of student learning outcomes in the regular class (control) and experimental class.

Table 5. Categorization of Learning Outcomes (Posttest) of Regular Class (Control) (XA) Students

Value Interval	Category	Total Students	Percentage (%)
85 - 100	Very good	0	0.00
75 - 84	Good	10	55.56
65 - 74	Enough	7	38.89
50 - 64	Not Enough	1	5.56
< = 49	Very less	0	0.00

Table 6. Categorization of Learning Outcomes (Posttest) of Experimental Class (XB) Students

Value Interval	Category	Total Students	Percentage (%)
85 - 100	Very good	14	82.35
75 - 84	Good	1	5.88
65 - 74	Enough	1	5.88
50 - 64	Not Enough	1	5.88
< = 49	Very less	0	0.00

Table 5 shows that out of a total of 18 students, 10 (55.56%) received a score in the 75-84 range, categorized as good. Meanwhile, 7 (38.89%) received a score in the 65-74 range, categorized as adequate. One (5.56%) received a score in the 50-64 range. Students did not achieve a score of 85-100, or very good, and no students received a score <49.

Table 6 shows that the score interval of 85-100, which is categorized as very good, was obtained by 14 students with a percentage of 82.35%. Meanwhile, the score interval of 75-84, which is categorized as good, was obtained by one student (5.88%). This percentage of 5.88% is the same as the score interval of 65-74, which is categorized as sufficient, and 50-64, which is categorized as poor, with each obtained by one student. No students had a score interval <49 (0%). Score categories in the posttest (daily test) class XA (regular class) and XB (experimental class of the SOPLE model) show that the value of class XB is much higher than that of class XA.

The descriptive analysis results show that the SOPLE learning model improves student learning outcomes. The significant increase in the average posttest score from 60.24 to 92.76 in the experimental class demonstrates this. Furthermore, the maximum pretest score for the experimental class was 93 and increased to 100 in the posttest. These results indicate that most students achieved high scores after the treatment.

The categorization of values in Tables 5 and 6 shows that in the regular class (control), the posttest scores of a total of 18 students, who obtained a score interval of 75-84 with the Good category, were 10 people or 55.56%. Meanwhile posttest of experimental class students (XB) showed that the score interval of 85-100 with the Very Good category was obtained by 14 students with a percentage of 82.35%. Meanwhile, the score interval of 75-84 in the Good category was obtained by one student (5.88%). In the experimental class (XB), students achieved the Very Good category, by 14 students while in the regular class (control), no students achieved the Very Good category. Regular class (control) students in the posttest only received scores below the experimental class, namely the Good category, by 11 students. This means that the posttest improvement of the experimental class after the SOPLE learning model treatment was very great.

This improvement occurred after students in the experimental class were taught using the SOPLE learning model, which systematically combines independent learning (self-study) with somatic, auditory, visual, and intellectual activities. Students gained a better understanding of environmental change and conservation through an active and structured learning process. This resulted in high exam scores.

In contrast to the experimental class, the regular class (control), although producing improved learning outcomes, did not achieve as significant a change as the experimental class. Conventional learning, which is more teacher-centered, likely results in limited student engagement in understanding the material. After the learning process, the distribution of grades became more uniform. The decrease in standard deviation and variance in both classes demonstrates this. Therefore, it can be concluded that the SOPLE learning model not only improves average learning outcomes but also evenly distributes grades.

These high learning outcomes indicate that students who received the SOPLE learning model treatment were able to understand what they read, saw, experienced, or felt based on their learning process in learning, including observations and research conducted. Experimental class students have higher process skills, especially in developing their basic mental, physical, and social abilities (Susanto, 2018).

N-Gain Student Learning Outcomes

To determine the extent of the increase in student learning outcomes from pretest to posttest that can be attributed to the treatment (the SOPLE learning model in the experimental class), an N-Gain calculation was performed for each class. This was calculated for each class and expressed as a score (value) and percentage. Then, to assess learning effectiveness, this value was interpreted according to the categories of high, medium, and low. The data are presented in Table 7 below.

Table 7. N-Gain Average of Student Learning Outcomes

Class	Pretest	Posttest	N-Gain Score	N-Gain (%)	N-Gain Interpretation
Experiment	60.24	92.76	0.8	80.0065	High/ Effective
Regular	69.28	75	0.089	8.9933	Low/Ineffective

Table 7 shows a clear difference between the two classes. The experimental class had an average N-Gain score of 0.800 (80.01%), which is categorized as **high/effective**, indicating that learning outcomes improved significantly after the implementation of the SOPLE model. On the other hand, the regular class (control) had an average N-Gain score of 0.089 (8.99%), which is categorized as low, indicating that there was almost **minimal** improvement from pretest to posttest.

While both groups showed an increase in mean scores from pretest to posttest (Experimental: 60.24 to 92.76; Regular: 69.28 to 75.00), the magnitude of the increase differed substantially. The relatively high N-Gain (0.80) in the experimental class indicates that there was a significant and highly effective increase in scores after the SOPLE learning model treatment, whereas the regular class experienced only a slight increase (0.089), which falls into the low improvement category.

The results of the N-Gain calculation show a striking difference between the experimental class and the regular class (control). The experimental class obtained an N-Gain score of 0.80 (80.01%) with a high category, which indicates that learning with the SOPLE model is able to improve student learning outcomes effectively. In contrast, the regular class (control) obtained an N-Gain score of only 0.089 (8.99%) with a **low category**, suggesting that the increase in learning outcomes in this class was **minimal** compared to the maximum possible gain.

In the experimental class, significant improvements indicated that students truly gained a better understanding after using the SOPLE model. This model provides students with the opportunity to learn actively through the stages of Self-Study, Opening, Practice, Listening, and Evaluation. During these stages, students not only passively receive information but also directly engage in the learning process. This is supported by external factors such as diverse learning resources, such as scanned textbooks and then shared with students, YouTube videos of learning materials, and PPTs. Furthermore, the school environment is conducive, safe, and provides a positive learning atmosphere. Classrooms are clean, tidy, and comfortable for learning. The school culture at St. Maria Iteng Private Senior High School upholds academic values, honesty, and encourages active student participation (Yandi et al., 2023).

In the regular class (control), the learning process remained conventional, resulting in lower student engagement, a lower increase in their understanding of concepts, and lower overall learning outcomes compared to the experimental class. A low N-Gain score indicates minimal student improvement and is classified as low effectiveness. Therefore, these findings indicate that, compared to conventional learning, the use of the SOPLE learning model significantly improves student learning outcomes.

Results of the Normality Test of Student Learning Outcomes

A normality test was conducted to determine whether the distribution of learning outcome data in the regular and experimental classes was normal. This test is crucial for determining the type of statistical test to be used in the following stages, whether parametric or non-parametric. This study used two normality test methods: Kolmogorov–Smirnov and Shapiro–Wilk, with a significance level of 0.05. Data are considered normal if the significance value is greater than 0.05, and abnormal if the significance value is less than or equal to 0.05. The data are presented in Table 8 below.

Table 8. Results of the Normality Test of Student Learning Outcome Data

		Kolmogorov-Smirnov		Shapiro Wilk	
Class		Sig.	Information	Sig.	Information
Results	Experiment Pretest	0.146	Normal	0.081	Normal
	Experiment Posttest	<0.001	Abnormal	<0.001	Abnormal
	Regular Pretest	0.061	Normal	0.064	Normal
	Regular Posttest	0.012	Abnormal	0.065	Normal

The results of the normality tests indicated that several data sets did not consistently meet the assumption of normality. Table 8 above shows that in the experimental class (pretest), the Kolmogorov–Smirnov significance value was 0.146 and the Shapiro–Wilk significance value was 0.081, each greater than 0.05, indicating that the data were normally distributed; in the experimental class (posttest), the significance value was less than 0.001, indicating that the data were not normally distributed.

In the pretest, the regular class (control) had a mark significance of 0.061 for Kolmogorov–Smirnov and 0.064 for Shapiro–Wilk, indicating a normal distribution. In the posttest, the regular class (control) had a significance value of 0.012 for Kolmogorov–Smirnov (not normal) and 0.065 for Shapiro–Wilk (normal). The data were considered not completely normal under these conditions because one of the tests (KS) showed non-normal results.

To ensure statistical prudence and the validity of the results, this study adopted a conservative decision rule: If either of the two normality tests (Kolmogorov–Smirnov or Shapiro–Wilk) indicated a non-normal distribution, or if the data from one of the two groups (experimental or regular) clearly violated the normality assumption, a non-parametric statistical test would be employed. Based on this rule, the normality assumption was determined not to be conclusively met. Specifically, the posttest data for the experimental class were proven to be non-normal by both tests, and the Kolmogorov–Smirnov test for the regular class also

indicated a significant deviation from normality (Sig = 0.012), contradicting the Shapiro–Wilk result. Consequently, the non-parametric Mann–Whitney U Test was selected to compare the learning outcomes between the two groups. This decision ensures that the conclusions drawn regarding the difference in learning outcomes are not biased by potential violations of the data normality assumption.

Results of the Homogeneity Test of Student Learning Outcomes

The homogeneity test was conducted to determine whether the data variance between the regular and experimental classes was homogeneous or equal. This examination process is crucial for determining the appropriate type of hypothesis test. In this study, Levene's homogeneity test was used with a significance level of 0.05. If the Sig. value is greater than 0.05, the data are homogeneous (equal variance), and if the Sig. value is less than 0.05, the data are not homogeneous (different variance). The data are presented in Table 9 below.

Table 9. Results of the Homogeneity Test of Variance of Student Learning Outcomes

		Levene Statistic	Sig.	Detail
Students' learning outcomes (Homogeneity)	Based on Mean	3,737	62	Homogeneous
	Based on Median	394	535	Homogeneous
	Based on Median and with adjusted df	394	537	Homogeneous
	Based in trimmed mean	2,237	144	Homogeneous

All Levene's test methods show significance values greater than 0.05, as shown in Table 9 above. For example, the significance value based on the median is 0.062, the medians are 0.535 and 0.537, and the median (trimmed mean) is 0.144. All these values indicate that there is no significant variation between the experimental class and the regular class (control).

The results of the homogeneity test show that the variance of both data groups is the same, which means that the distribution of learning outcome data between the regular and experimental classes is almost the same. Although the data met the homogeneity requirements, the results of the previous normality test showed that some data had a non-normal distribution, especially in the posttest. Because the assumption of normality was not fully met, despite being homogeneous, hypothesis testing was still carried out using the Mann–Whitney U test, which is non-parametric. Therefore, the Mann–Whitney U test was the appropriate choice for this study because the data variance was homogeneous; some data did not have a normal distribution; and the non-parametric test was more suitable since the number of samples for each group was not large.

Hypothesis Test Results (Mann-Whitney U) on Student Learning Outcomes

Hypothesis testing was conducted to determine whether there were significant differences in learning outcomes between the experimental class using the SOPLE learning model and the regular class (control) using conventional learning. The non-parametric Mann–Whitney U test was used to test the hypothesis. This was done

because the results of the normality test indicated that the posttest data did not have a normal distribution. When the normality assumption is not met, this test is suitable for comparing two independent groups. The data are presented in Tables 10 and 11.

Table 10. Results of the Mann-Whitney U Test on Student Learning Outcomes

Test Statistic ^a	Real Difference Results of Experimental Class Posttest and Regular Class Posttest
Man-Whitney U	34
Wilcoxon W	205
Z	-4.017
Asymp. Sig. (2-tailed)	< 0.001
Exact Sig. [2*(1-tailed Sig.)]	< 0.001

Table 11 Mean Rank Value of Student Learning Outcomes

	Class	N	Mean Rank	Sum of Ranks
Real difference results (there is an increase in results learn significantly)	Posttest of Experiment Class	17	25,00	425,00
	Posttest of Regular Class	18	11,39	205,00
	Total	35		

As evidence that student learning outcomes in the experimental class tend to be better than those in the regular class (control), Table 11 shows that the mean rank of the experimental class is 25.00, much higher than that of the regular class (control) 11,39. This difference is shown as statistically significant in Table 10, as indicated by the Mann–Whitney U value of 34.000 and the asymptotic sig. (2-tailed) value of <0.001 (smaller than the 0.05 significance level). This indicates that the difference is statistically significant between the experimental and regular classes.

In the final test (posttest) of the experimental class and regular class (control), the Mann–Whitney U value = 34,000, $Z = -4.017$, and the asymptotic significance (2-tailed) is <0.001, far below the 0.05 significance level. The results of the Mann–Whitney U test indicate a significant difference in learning outcomes between the experimental class and the regular class (control). These results indicate that students tend to have significantly higher learning scores in the experimental class than in the regular class (control). In addition to assessing significance, this study also calculated the effect size (r) to determine the extent of the treatment's influence. To determine the effect size, the following formula was used.

$$r = [Z : \sqrt{N}]$$

With $Z = -4.017$; $N = 35$

$$r = 4.01735 : \sqrt{35} = 4.017 : 5.916 = 0.68$$

The SOPLE learning model significantly influences student learning outcomes, as indicated by the r value = 0.68, which is in the large category (Cohen, 1988). Based on the results of this test, the decision regarding the hypothesis is

- H_0 (null hypothesis) rejected: There is no significant difference in learning outcomes between the experimental class and regular class (control) on the material of Environmental Change and Conservation in class X St. Maria Iteng Private Senior High School, Manggarai, NTT.
- H_1 (alternative hypothesis) is accepted: There is a significant difference in posttest learning outcomes between the experimental class and regular class (control) on the material of Environmental Change and Conservation in class X St. Maria Iteng Private Senior High School, Manggarai, NTT.

The results of the hypothesis test showed that there was a statistically significant difference between the two groups (posttest of the experimental class and posttest of the regular class (control)). This decision was made because the p -value was <0.05 . These results confirm that the SOPLE learning model is effective in improving students' biology skills, especially regarding the environment (material on environmental change and conservation). Students are motivated to actively participate in the learning process through the SOPLE stages: Self-Study, Opening, Practice, Listening, and Evaluation. Students not only receive information passively but also learn to collaborate and understand concepts independently, which improves their conceptual understanding.

Teacher-centered learning tends to decrease student participation and engagement. This is indicated by lower posttest scores in the regular class (control) and lower average rankings. Therefore, the results of the Mann–Whitney U test and the effect size (r) calculation demonstrate statistically and practically that the implementation of the SOPLE model has a significant and substantial impact on improving student learning outcomes.

Factors supporting significant improvements in learning outcomes include the SOPLE learning model, which is able to increase student learning motivation, encourage teachers to improve their competencies through good teaching preparation, create dialogic-assertive communication between teachers and students, build learning discipline and classroom management, and improve students' self-management skills. These factors support significant improvements in grades after the SOPLE learning model is implemented (Yandi et al., 2023).

The uniqueness of the SOPLE learning model is that it can accommodate five of the eight types of intellectual intelligence possessed by humans according to Gardner: linguistic, logical-mathematical, kinesthetic, interpersonal, and naturalist (Jaya et al., 2023). This model is applied to the material of environmental change and conservation and has been proven to significantly improve student learning outcomes. Howard Gardner advanced the theory of Multiple Intelligences. Through this theory, Gardner emphasizes the importance of respecting the uniqueness of each individual with different learning styles. Gardner also encourages the development of more diverse assessment models to measure a person's intelligence more fairly (Musfiroh, 2017).

Handoyo and Asy'ari (2019) researched the use of the surrounding environment as a science learning laboratory in the development of multiple intelligences of Elementary School Teacher Education (PGSD) students at Sanata

Dharma University. The results showed an increase in students' understanding of science concepts, as well as an increase in aspects of biological intelligence, especially logical, interpersonal, intrapersonal, naturalist, linguistic, musical, and kinesthetic intelligence in students. This study proves that the SOPLE learning model, which contains 5 elements of intellectual intelligence, improves students' understanding of science and various aspects of biological intelligence.

The SOPLE learning model, which has been proven to significantly improve student learning outcomes, confirms that the SAVI element in it has accommodated the full use of students' senses with various activities such as physical activity (somatic), speaking and listening (auditory), observing and describing (visualization), and solving problems and thinking critically (intellectually). By utilizing these senses fully, students are inspired by their enthusiasm and interest in participating in the learning process so that the learning can run optimally. (Rusman, 2016). This is in line with research evidence from Setiyaningsih et al. (2022); the SAVI learning model has a significant influence on increasing HOTS and student self-regulation, with a significance value of 0.000 ($p < 0.05$).

The SOPLE learning model also accommodates the flipped classroom learning model, which involves in-class learning with out-of-class learning. The goal is to maximize learning activities. Students learn the material from the teacher at home, and in this study, students appeared more prepared to learn in class. They actively asked questions, especially during other groups' presentations, and sought confirmation from the researcher as the teacher (Rakhmawati & Choiriyah, 2023). Research by Susilawati (2020) showed that the practice of the flipped classroom learning model improved students' understanding of the whole-mount material (pollen and spore acetolysis), with an N-Gain percentage of 43.76% for the regular class (control) and 64.87% for the experimental class. Consistent with previous research, Herrani (2020) demonstrated that the application of flipped learning on microbiology material integrated with a learning management system improved students' understanding, with a score of 3.4 for class A and 3.5 for class B. The implementation of flipped learning on Microbiology material integrated with an LMS, based on learning evaluation results, was categorized as very good. Research by Fitriani et al (2023) shows that the Flipped classroom learning model increases student activity and learning outcomes in biodiversity material for class X-3 of SMA Negeri 1 Gowa in 2023, with the percentage (learning outcomes) of the cognitive domain, the average test score for cycle I reaching 55.56%, and cycle II reaching 76.47%.

The SOPLE learning model is also supported by the theory of social constructivism. The concept of constructivism is based on the psychological and philosophical idea that people actively construct their own understanding and knowledge. The main principle of constructivism is that knowledge is not something given by teachers to students, but rather the result of a construction process carried out by individuals themselves. The curriculum used in the SOPLE learning model is the Independent Curriculum, making it highly compatible with strengthening the profile of Pancasila students, which provides ample space for student experience and active involvement both in and outside the classroom (Nerita et al., 2023).

Conclusion

The study discovered that using the SOPLE (Student-Oriented Learning in Environmental Education) learning model successfully enhanced biology students' learning results, especially when it came to environmental subjects. This difference was significant, suggesting a big effect size in favor of the SOPLE model-using experimental group. According to this research, SOPLE is a very successful teaching strategy for raising student performance and cognitive engagement in environmental biology classes. Compared to traditional training, the model's focus on student-centered projects and environmental context effectively promoted deeper understanding and improved subject-matter mastery.

The findings have important relevance for biology education methodology and curriculum development. The SOPLE model, which can foster higher-order thinking abilities necessary for environmental literacy in addition to factual memory, provides a strong and practical substitute for conventional teaching techniques. In order to educate students for practical problem-solving, we advise its adoption, especially in courses that concentrate on intricate, real-world concerns like environmental science.

There are a number of limitations to this study that should be taken into consideration for future research.

1. Time Restrictions

The SOPLE model involves a significant amount of time for project implementation, which occasionally surpasses the allotted class time. Strategies to more effectively incorporate the model into regular academic timetables should be explored in future implementations.

2. Sample Size and Attrition

Only students with complete attendance and assessment data (pretest and posttests) were included in the final data analysis. The studied sample size was reduced due to student absences and incomplete pretest and posttest. Ten students (five per class) were designated for instrument validation and subsequently excluded from the primary data analysis to maintain independence.

3. Assessment Scope

Only the cognitive component of learning outcomes was included in the current evaluation. In order to provide a more thorough picture of SOPLE's overall impact on student development, future research should include tools to assess the affective and psychomotor domains.

4. Operational Constraints

Due to issues with student data constraints and school internet connectivity, the researcher had to manually distribute surveys and provide an internet hotspot during class. Although these problems were resolved, they highlight possible challenges in expanding the SOPLE model in environments with insufficient technology infrastructure.

Future studies could concentrate on the model's efficacy across various biological disciplines and educational levels, the long-term retention of learning outcomes, and the influence of SOPLE on non-cognitive skills (affective domain and psychomotor domain).

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TRENDS AND THEMATIC DIRECTIONS CULTURALLY RESPONSIVE TEACHING ON STUDENTS' WRITING SKILLS IN MULTICULTURAL CLASSROOMS: A SYSTEMATIC LITERATURE REVIEW

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Received: 27 November 2025; Accepted: 6 December 2025

Abstract

This study presents a systematic review of the development of Culturally Responsive Teaching (CRT) in the teaching of writing skills within multicultural classrooms. The review aims to identify patterns in research development, map publication trends and thematic distributions, and interpret the theoretical and practical implications of existing findings to propose future research directions. The review procedure follows PRISMA guidelines, using Scopus-indexed publications up to 31 October 2025 as the primary data source, complemented by bibliometric analysis conducted with VOSviewer to reveal the intellectual structure and dynamics of the field. The findings indicate that research on CRT in writing instruction predominantly addresses the integration of students' linguistic and cultural backgrounds, identity reinforcement, and inclusive instructional design. The theoretical insights confirm CRT's contribution to enhancing instructional relevance and students' critical awareness, while practical implications are reflected in increased student engagement and improved writing performance. Identified research gaps highlight the need for conceptual studies in developing-country contexts, longitudinal examinations, and the development of adaptive CRT pedagogical models aligned with technological advancements.

Keywords: culturally responsive teaching, multicultural classroom, systematic literature review, writing skills

Introduction

Global social changes over the past several decades have substantially influenced educational dynamics worldwide, including in Indonesia. Within contemporary learning environments, classrooms have increasingly become spaces where students from diverse ethnic, linguistic, and cultural backgrounds converge. Such diversity has become an inherent feature of daily instructional practices, as the social realities each student brings shape distinct ways of thinking, value systems, and cultural practices (Civitillo et al., 2019; Liu et al., 2021). These developments have necessitated the reformulation of inclusive educational practices through the adoption of pedagogical approaches that are responsive to ongoing social transformation (Tsokalidou & Skourtou, 2020).



Culturally Responsive Teaching (CRT) is widely recognised as an approach capable of bridging the gap between students' cultural identities and school-based learning practices (Petri et al., 2025). CRT positions students' cultural knowledge as an integral component of instruction, encouraging the use of pedagogical strategies and learning materials that align with learners' sociocultural contexts. These adaptations are intended to foster more meaningful and transformative learning experiences (Ladson-Billings, 1995; Pathomchaiwat & Thongrin, 2025). Nevertheless, the implementation of CRT in language education continues to encounter several challenges. Many teachers do not yet possess the pedagogical and cultural competencies necessary to navigate the complexities of diverse learning environments (Masunungure & Maguvhe, 2025; Schachner et al., 2016). Furthermore, limited access to training in culturally responsive pedagogy, coupled with teachers' ongoing reliance on conventional instructional methods, further constrains the effective implementation of CRT in language learning contexts (Matiso, 2024).

Writing involves several stages, including planning, drafting, and revising, which contribute to the clarity and accuracy of the text produced (Hyland, 2003). Writing proficiency requires the ability to organise ideas in accordance with grammatical rules, arrange information logically, and express meaning clearly and appropriately (Bal & Öztürk, 2025; Grabe & Kaplan, 1996). In language-learning contexts, studies indicate that students continue to encounter difficulties in writing, such as challenges in generating ideas, maintaining coherence within paragraphs, developing arguments, and applying an academic writing style (Alzahrani, 2025; Habeb Al-Obaydi et al., 2025; Toba et al., 2019). Pedagogical practices that emphasise mechanical exercises or product-oriented instruction may also limit opportunities for students to engage in meaning-making processes (Siekman et al., 2022). These observations suggest the need for a systematic review of empirical studies that examine factors influencing students' writing performance and the pedagogical approaches used to support writing development in different learning settings.

Classroom environments characterised by cultural diversity present several issues that require consideration. Differences in cultural backgrounds between teachers and students often require skills in cultural adaptation and conflict management to maintain effective classroom interaction (Avagimyan et al., 2023). Some teachers also report limited preparedness for working with diverse student populations, which affects the implementation of culturally responsive pedagogy (Kim & Cooc, 2023). Interactions shaped by implicit cultural norms or power relations may lead to misunderstandings. In addition, cultural and linguistic diversity in the classroom may be associated with psychosocial challenges that influence students' participation and learning processes (Güven et al., 2023; Parkhouse et al., 2019).

Empirical studies indicate that various components of Culturally Responsive Teaching (CRT) are associated with the development of students' writing skills in multicultural classroom settings. A literature review by Bakogiannis and Papavasiliou (2025) reports that inclusive instructional practices that draw on students' linguistic repertoires and cultural backgrounds can support idea development and participation in academic writing. These observations are supported by Ajani (2024), who emphasises that pedagogical and digital training

informed by CRT is important for designing writing tasks that are contextual, culturally relevant, and aligned with students' needs. Similarly, a critical review by Chang and Viesca (2022) suggests that the effectiveness of CRT is closely related to teachers' critical awareness of power relations and curricular biases that may influence how students' writing is evaluated. Dediwalage et al. (2025) further highlight the role of social relationships between teachers and students in shaping academic habits and cultural capital, both of which contribute to literacy performance among students from diverse cultural backgrounds. The use of multicultural literature has also been shown to support the development of critical awareness, empathy, and intercultural communication skills, which can contribute to writing development within culturally responsive instructional frameworks (Lin et al., 2025; Xu et al., 2024).

Based on the reviewed studies, all six SLR publications underline the importance of culturally responsive pedagogy in multicultural education, although each addresses a different focus compared with the present study. Ajani (2024) examines teachers' preparedness for addressing linguistic diversity through the integration of pedagogy and technology, whereas Xu et al. (2024) emphasise the use of multicultural literature to develop intercultural communication skills. Lin et al. (2025) focus on the integration of multimodal AI to enhance participation and exploration in the writing process as part of multicultural identity development, while Dediwalage et al. (2025) highlight the influence of cultural capital, habitus, and power relations on the learning experiences of both teachers and students. Studies by Bakogiannis and Papavasiliou (2025) and Chang and Viesca (2022) similarly address issues related to cultural representation, the effectiveness of culturally responsive strategies, and pedagogical gaps in multicultural classrooms. The alignment between previous studies and the present research lies in their shared attention to inclusive pedagogy, acknowledgement of linguistic diversity, and efforts to enhance multicultural literacy. The distinctions, however, relate to scope and analytical focus. This study contributes novelty by providing a synthesis of CRT research specifically within the context of writing instruction, including an examination of trend distributions, methodological patterns, and the theoretical and practical implications for instructional design in multicultural classrooms.

Research on the influence of Culturally Responsive Teaching (CRT) on students' writing skills in multicultural classrooms is increasingly relevant in the current educational context. First, globalisation and growing socio-cultural mobility have contributed to greater ethnic, linguistic, and identity diversity in Indonesian classrooms. These conditions require pedagogical approaches that can support students' academic performance (Mi Min et al., 2025; Zeng et al., 2025). Second, the application of CRT principles in writing instruction is shaped by socio-cultural dynamics, teacher readiness, and the broader educational context in Indonesia. In this regard, systematic literature reviews (SLRs) can help clarify the mechanisms through which culturally grounded instructional strategies facilitate students' literacy engagement (Ghaemi & Boroushaki, 2025; Ibrahim & Johnson, 2021). Third, SLRs make it possible to identify research gaps in this field, including the limited number of studies that specifically address writing skills in Southeast Asian contexts, the predominance of qualitative approaches, and the need for greater methodological variety in future research (Montgomery & Rubin, 2025; Xu et al., 2024). Mapping these gaps enables clearer direction for subsequent empirical

studies aligned with the needs of multicultural education in Indonesia. In addition, the findings of this SLR have practical implications for the development of an inclusive writing curriculum, the enhancement of teacher competencies through culturally responsive training, and the formulation of policies related to resource allocation aimed at strengthening culturally and equity-oriented pedagogical practices.

Based on the above considerations, this study aims to identify and describe the development of research on Culturally Responsive Teaching (CRT) in writing instruction within multicultural classroom settings, both in current scholarship and in potential future directions. In addition, the study analyses publication trends and the distribution of research foci related to CRT in writing instruction in multicultural classrooms. Furthermore, it interprets the theoretical and practical implications of previous findings to formulate future research directions and provide recommendations that are relevant to the development of CRT in writing instruction in multicultural educational contexts.

Culturally Responsive Teaching (CRT)

Culturally Responsive Teaching (CRT) is a pedagogical approach that incorporates students' cultural backgrounds, experiences, and perspectives into the learning process to ensure that instruction is relevant and contextually grounded. This approach assumes that learning becomes more meaningful when teachers establish connections between instructional content and students' cultural identities, particularly in multicultural classroom settings (Gay, 2018; Rhodes & Lohr, 2021). A central principle of CRT is the development of teachers' cultural awareness, enabling them to understand students' cultural identities and characteristics. Such awareness supports the creation of learning environments that value diversity and promote active student participation (Cruz et al., 2020).

CRT also emphasises student empowerment through the recognition of their cultural backgrounds (Ladson-Billings, 2009). It is regarded as an orientation toward social justice, as teachers are expected not only to deliver academic content but also to cultivate respect for diversity (Nieto, 2013). The CRT framework highlights the integration of cultural knowledge into instructional processes, which contributes to the development of culturally informed knowledge structures. To implement this approach effectively, teachers must possess explicit understandings of cultural diversity as part of their professional readiness (Bayraklı, 2026a; Bernier et al., 2025). Based on these perspectives, CRT can be synthesised as a pedagogical approach that seeks to address structural inequities within the education system. By positioning students' cultural backgrounds as a central component of curriculum and instructional practice, CRT supports the development of learning experiences that are relevant, meaningful, and inclusive. At the same time, it promotes students' cultural competence and strengthens their social awareness, thereby preparing them to participate critically in a diverse and pluralistic society.

Teaching Writing Skills

The development of writing skills involves complex cognitive and social processes, requiring writers to organise their thoughts, overcome challenges, and iteratively revise and construct ideas that initially may be abstract, ultimately shaping them into coherent and structured expressions (Murray & Moore, 2006).

From a constructivist perspective, writers are viewed as active learners who generate meaning by integrating new knowledge with their existing cognitive frameworks. Writing activities enable learners to consolidate prior knowledge while simultaneously constructing new understanding through processes of internalisation and cognitive restructuring (Hoang & Hoang, 2024; Taraj et al., 2025).

Acquiring writing skills allows students to effectively communicate thoughts, information, ideas, and emotions to an audience. Writing functions both as a process and a product, providing students with a medium to explore and articulate their ideas (Msuya & Abdala, 2025; Popp, 2005). Consistent with this view, Kumar (2020) posits that writing is a mental process that begins with the integration of diverse ideas, which are subsequently organised into coherent phrases and sentences to form complete texts. The writing process, encompassing feedback, self-evaluation, critical reflection, and guided instruction, fosters the development of independent, critical, and self-aware writers (Matczak et al., 2025). The perspectives suggest that learning to write is a constructive, iterative process that emphasises collaboration, reflective practice, and the enhancement of cognitive abilities, ultimately enabling students to produce comprehensive and meaningful written texts.

Multicultural Classroom Context

Multicultural education is designed to promote a just and equitable society, free from oppression. It responds to the realities of cultural diversity by emphasising ethnic identity, cultural pluralism, equitable distribution of resources and opportunities, and the socio-political challenges arising from historical discrimination (Degaga & Mekuria, 2023). Contemporary perspectives position multicultural education as a framework that fosters equal access, active participation, and meaningful interaction among students, while cultivating reflective, tolerant, and globally minded citizens (Williams & Soriero, 2021). In accordance with this view, Banks (2020) asserts that multicultural education upholds the principle that all students—regardless of gender, social class, or ethnic, racial, or cultural background—should have equitable learning opportunities.

Multicultural classrooms provide a conducive context for developing conflict resolution skills and facilitating cross-cultural exchange. Within these environments, multicultural education functions as a mediator that mitigates prejudice and fosters an inclusive and supportive classroom atmosphere (Oubkkou, 2024). Collaborative learning activities promote social cohesion by strengthening interpersonal relationships, reducing social distance, and enhancing cross-cultural networks. Sustained engagement in intercultural interactions supports the development of competencies such as cross-cultural communication, adaptability, and collaborative skills in multilingual and multi-ethnic settings (Ganesan & Morales, 2024; Ioannou & Constantinou, 2018). Moreover, multicultural education contributes to the cultivation of a global citizenship identity that values diversity, critically engages with social issues, and recognises collective humanitarian responsibility (Benediktsson, 2022). Synthesising these perspectives, multicultural classrooms can be conceptualised as dynamic spaces that integrate three interrelated dimensions: a cognitive dimension, emphasising perspective-taking and critical reflection; a socio-affective dimension, fostering empathy, social cohesion, and

prejudice reduction; and a global competency dimension, focused on the development of socio-cultural abilities in diverse contexts.

Method

This study employed a Systematic Literature Review (SLR) approach. This method was selected because it offers a scientific and structured procedure for synthesising existing literature, identifying research gaps, examining patterns of findings, and outlining the trajectory of current scholarship. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines as recommended by Moher et al. (2009) and Paul and Criado (2020). In accordance with these standards, the review outlines the eligibility criteria, sources of information, data collection procedures, extracted data items, and strategies for synthesising findings to address the research questions. The review focused specifically on peer-reviewed journal publications that examine culturally responsive teaching (CRT) and its influence on students' writing skills within multicultural classroom settings. Scopus was selected as the primary database due to its extensive global coverage, rigorous indexing requirements, and advanced search functionality. The review process consisted of three main stages: identification, screening, and eligibility assessment.

The identification stage involved a systematic search of the Scopus database. This process included: (1) determining the publication range up to 31 October 2025; (2) applying keywords relevant to the focus of the study—culturally responsive teaching, writing skills, multicultural classrooms, and language learning; and (3) retrieving all potentially relevant articles for further examination. Following data retrieval, a bibliometric analysis was conducted using VOSviewer to visualise bibliographic patterns, including citation networks, author collaborations, and frequently occurring keywords. This analysis provided insights into the intellectual structure and evolution of the research field. The integration of bibliometric techniques with the systematic review process enhances the robustness of the analysis by enabling the mapping of research landscapes, identifying influential contributors, and examining emerging trends. (Donthu et al., 2021; Zupic & Čater, 2015). This methodological combination contributes to a more comprehensive understanding of empirical developments, conceptual frameworks, opportunities for future research, and the broader theoretical and methodological contributions to interdisciplinary scholarship.

A more detailed screening process was carried out in two stages. The first stage involved screening titles and abstracts, followed by a full-text review. This process was guided by inclusion criteria that had been established systematically, which comprised: publications dated between 2015 and 2025; empirical research designs; articles published in English; alignment of the research context with the focus of this study; and the use of evaluation methods involving experimental or quasi-experimental procedures with tests or specific instruments to measure the impact of culturally responsive teaching (CRT). The eligibility stage was then conducted to verify the final suitability of the selected publications. This stage included removing duplicate records, confirming the language and document format, reassessing contextual relevance, and ensuring the completeness of the empirical data required for analysis. These steps ensured that only studies meeting all conceptual and methodological criteria were included in the final synthesis. The

research procedure is illustrated through a methodological flow diagram, which outlines the process from initial identification to the final selection of eligible studies, as presented in Figure 1.

Based on the search results obtained from publications indexed in the Scopus database up to 31 October 2025, using the specified terms in the article title, abstract, and keywords, including the phrases culturally responsive teaching, culturally responsive pedagogy, culturally relevant teaching, writing skills, writing performance, multicultural, and diverse classroom, a total of 119 documents were identified across various academic disciplines. These publications ranged from the year 2002 to 2025. After the initial retrieval, a verification procedure was applied to ensure that all studies met the required publication period. This process resulted in the removal of 15 articles that fell outside the designated publication window from 2015 to 2025, leaving 104 for further analysis.

The subsequent screening phase involved examining documents based on their classification and relevance to the review criteria. During this stage, several document types were excluded, including book chapters, review articles, books, conference proceedings, and notes, resulting in a total of 24 documents removed. Following this screening process, 76 documents remained. A language-based exclusion was then conducted to ensure consistency with the analytical requirements, in which 2 publications written in Mandarin and 1 in Spanish were removed due to their language of publication, which did not align with the criteria requiring studies to be published in English. The final eligibility assessment served as an iterative process to identify studies that satisfied all inclusion criteria for the present review. After completing all exclusion procedures, a total of 73 articles were confirmed as eligible and were subsequently subjected to an in-depth synthesis during the final stage of analysis.

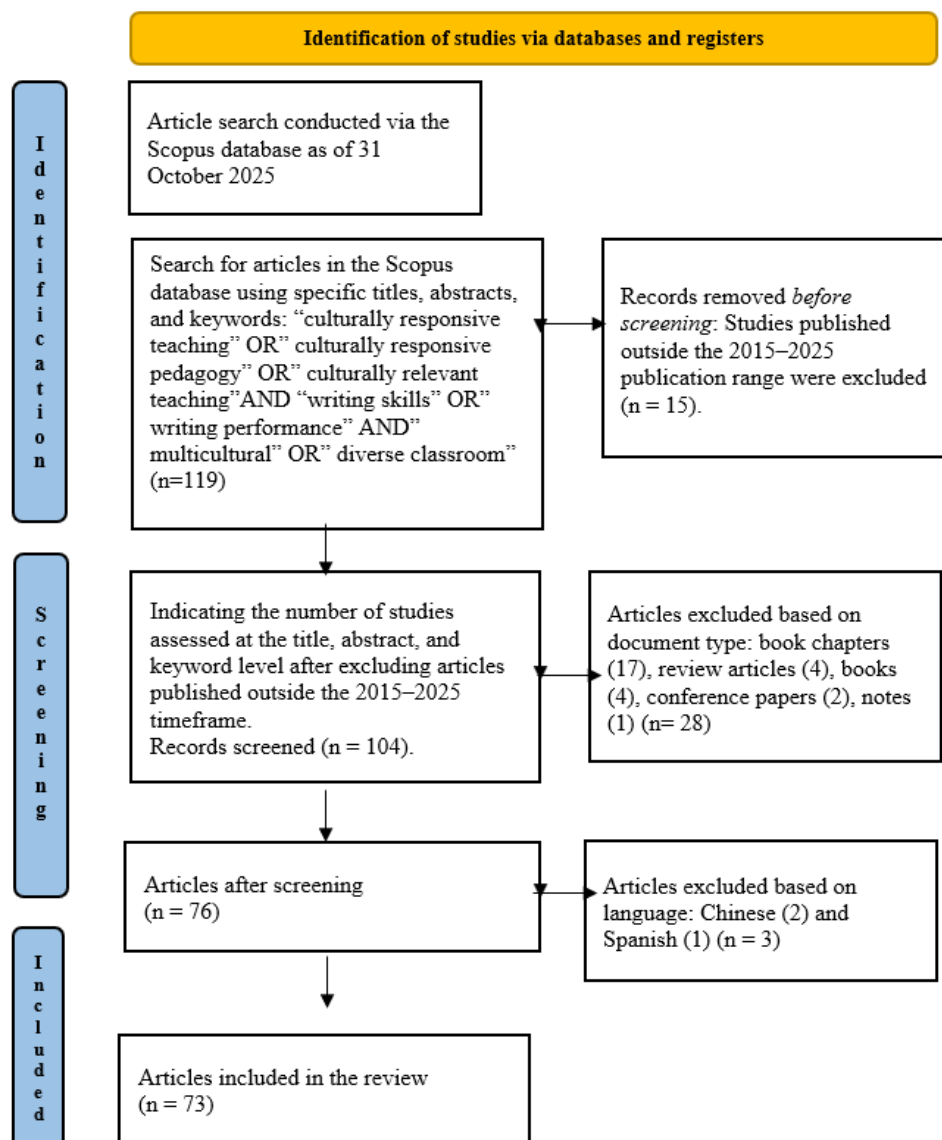


Figure 1. Systematic Literature Review Information Flow using PRISMA

Findings and Discussion

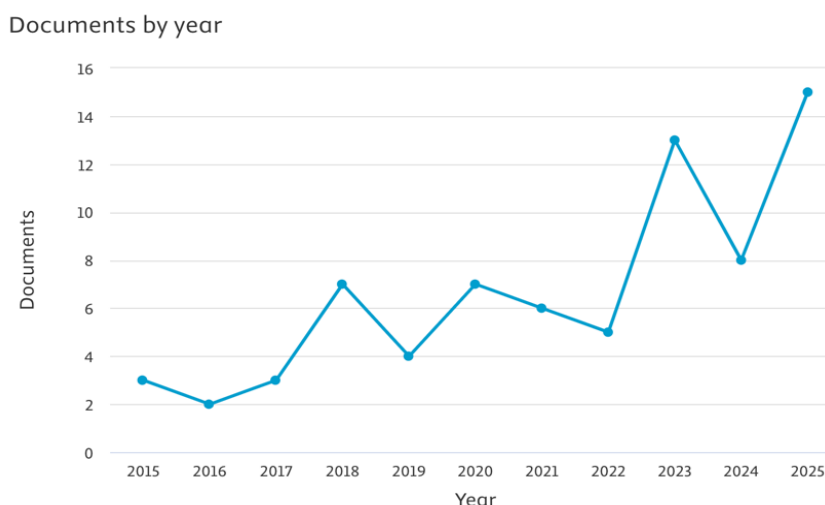
The findings of this study are derived from the analysis of 73 articles indexed in the Scopus database that examine the application of Culturally Responsive Teaching in writing instruction within multicultural classroom contexts. The review encompasses publication volume, annual publication trends, and the distribution of source types. In addition, the analysis identifies the most influential themes within the literature and maps the contributions of authors, affiliated institutions, and countries that have played a central role in advancing scholarship on Culturally Responsive Teaching in writing pedagogy.

The Development of Culturally Responsive Teaching Research in Writing Instruction in Multicultural Classrooms

An examination of publication data from 2015 to 2025 reveals a gradual yet uneven increase in research on Culturally Responsive Teaching in writing

instruction for multicultural classroom settings. Although the overall trajectory shows an upward trend, year-to-year fluctuations indicate that scholarly attention to this topic remains limited, as illustrated in Figure 2. Between 2015 to 2017, publication numbers were consistently low, with only two or three documents appearing each year. This period reflects the early phase of scholarly engagement, during which the integration of culturally responsive principles into writing instruction had not yet gained substantial recognition within the international academic community. A notable increase occurred in 2018, when seven publications were recorded. This growth suggests a rising awareness of the importance of cultural responsiveness in writing pedagogy and its potential to support learners in diverse educational settings.

The period from 2019 to 2022 shows a fluctuating pattern, with annual publications ranging from four to seven. This variability aligns with broader shifts in educational research priorities, including the global movement toward more inclusive pedagogical approaches. External factors such as the global pandemic also shaped research directions, contributing to changes in the intensity and focus of scholarly output during these years. The most significant rise occurred in 2023, which recorded thirteen publications (Anyichie et al., 2023a; Anyichie et al., 2023b; Anyichie & Butler, 2023; Appel & Lee, 2023; Baidoo-Anu et al., 2023; Choi, 2023; Garces-Bacsal, 2022; Idrus & Sohid, 2023; Kim & Cooc, 2023; Koirala, 2023; Kumi-Yeboah & Amponsah, 2023; M. Lee & Mo, 2023; Shockley & Ellis, 2023). This notable increase reflects heightened global attention to inclusive and culturally responsive pedagogical frameworks. The post-pandemic context further emphasised the need to strengthen learning quality, including writing instruction, through adaptive approaches that acknowledge cultural diversity. After reaching this peak, publications declined to eight in 2024. However, this trend reversed in 2025, which recorded fifteen publications, representing the highest annual output within the 10-year period under review. This surge indicates growing academic commitment to exploring culturally responsive approaches in the teaching of writing within increasingly diverse classrooms.



Source: Scopus Database

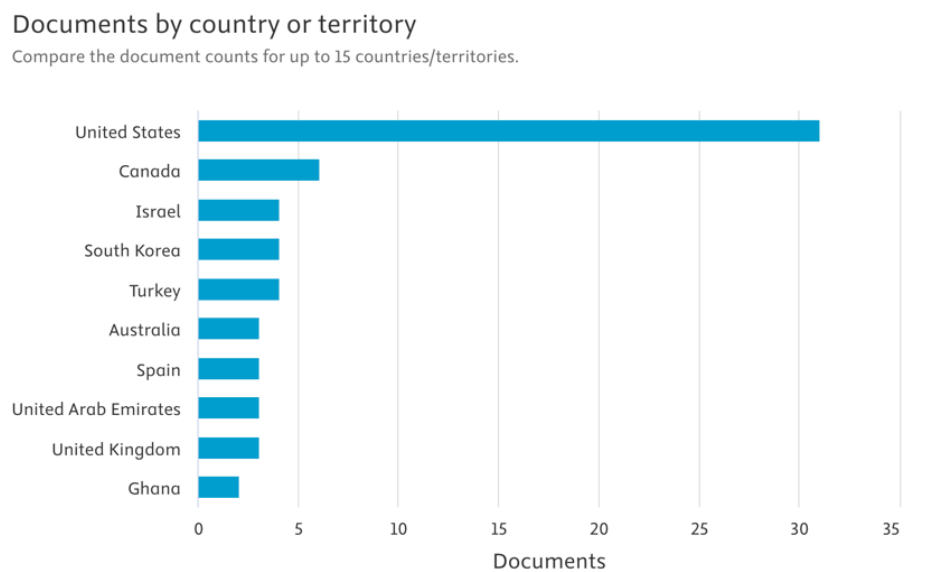
Figure 2. Number of CRT Studies on Writing Skills in Multicultural Classrooms

In line with the thematic mapping of this review, the publication trends over the past 10 years demonstrate that the body of literature on Culturally Responsive Teaching in writing instruction remains limited and insufficiently explored. The relatively small number of publications in the earlier years, followed by a gradual increase in subsequent periods, highlights the presence of a substantial research gap. This gap presents important opportunities for scholars to extend theoretical perspectives, broaden empirical investigations, and design writing instruction models that more effectively respond to cultural diversity in contemporary classrooms. The notable growth in research output in recent years suggests that CRT in writing instruction has increasingly become a focal point in educational discourse, particularly in efforts to advance equitable, adaptive, and culturally attuned pedagogical practices across diverse learning environments.

Mapping Publication Trends and the Distribution of CRT Research in Writing Instruction in Multicultural Classrooms

The analysis of the 73 articles included in this review classifies the distribution of CRT-related research according to country, region, institutional affiliation, source type, and contributing authors, with the top ten countries reported for each category. Mapping the distribution of research in this manner provides valuable insights for academics and practitioners and supports the development of more systematic and strategic directions for future scholarly inquiry.

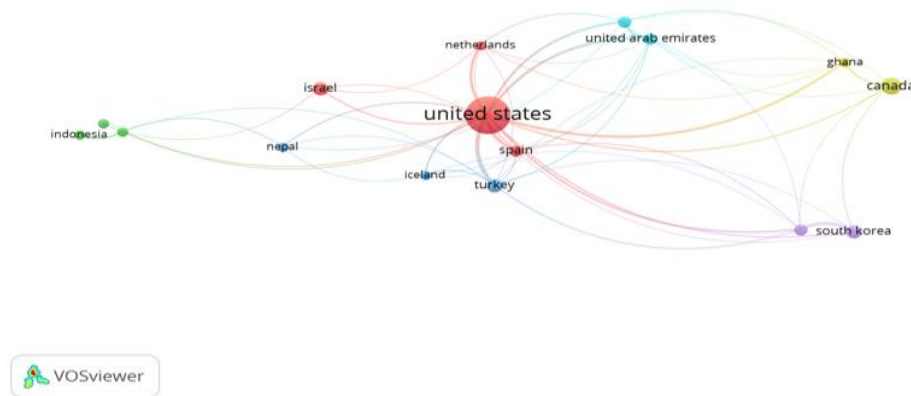
The first layer of distribution focuses on publications by country or geographic region. As illustrated in Figure 3, the United States emerges as the most prominent contributor with 31 publications. This is followed by Canada with six publications; Israel, South Korea, and Turkey with four publications each; Australia, Spain, the United Arab Emirates, and the United Kingdom with three publications each; and Ghana with two publications. This distribution reflects the varied levels of engagement with CRT-oriented writing instruction across different educational systems and cultural contexts (Figure 3).



Source: Scopus Database

Figure 3. Distribution of Articles by Country or Territory (Top 10 Countries)

In this study, collaboration patterns among countries engaged in CRT research were also examined using VOSviewer software. This analysis was undertaken to identify the structure of international research linkages and to inform potential directions for future scholarly development. The visualisation produced by VOSviewer illustrates the network of relationships among countries contributing to research on CRT in writing instruction within multicultural classroom settings (see Figure 4).



Source: VOSviewer Output

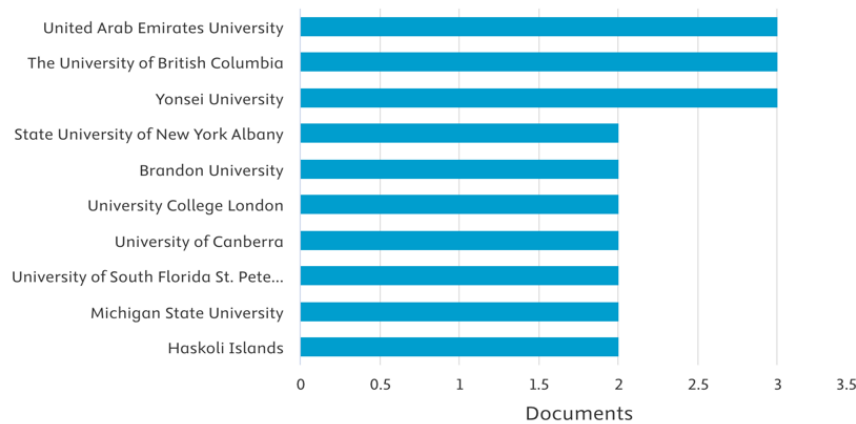
Figure 4. Network Country Visualisation

The network visualisation indicates that research on culturally responsive pedagogy has gained prominence in countries with longstanding histories of ethnic and cultural diversity. It also shows a growing presence of such studies in countries characterised by varied socio-cultural contexts. This pattern suggests that the topic remains highly relevant for addressing the complexities of diversity within contemporary education systems.

The second aspect of the analysis concerns the distribution of journal publications on CRT in writing instruction according to institutional affiliation. The results show that the United Arab Emirates University, the University of British Columbia, and Yonsei University each contributed 3 publications. Several institutions produced 2 publications, including the State University of New York Albany, Brandon University, University College London, the University of Canberra, the University of South Florida St. Petersburg, Michigan State University, and Háskóli Íslands. These findings are presented in Figure 5.

Documents by affiliation

Compare the document counts for up to 15 affiliations.



Source: Scopus Database

Figure 5. Network Country Visualisation

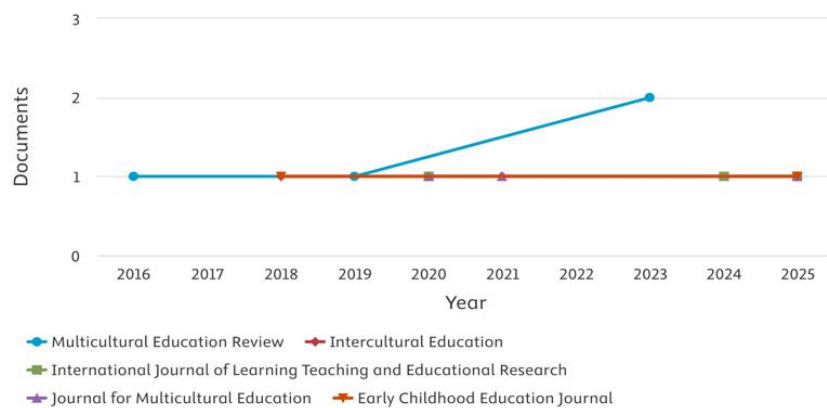
The analysis of institutional affiliations indicates that research contributions are concentrated within universities that have established policy orientations and research capacities related to educational diversity. These findings suggest that the distribution of CRT research is shaped by several factors, including institutional academic strength, demographic characteristics, and organisational structures. Understanding these dynamics provides a useful basis for formulating long-term directions for CRT research.

The third aspect of the analysis concerns the distribution of CRT-related publications by source. The *Multicultural Education Review* appears as the most frequent outlet, publishing 2 articles on this topic in 2023 and 1 article each in 2016 and 2019. Additional contributions were identified in the *Early Childhood Education Journal* in 2018 and 2025, the *Journal for Multicultural Education* in 2020 and 2021, and the *International Journal of Learning, Teaching and Educational Research* in 2024. These publication patterns are illustrated in Figure 6.

Documents per year by source

Compare the document counts for up to 10 sources.

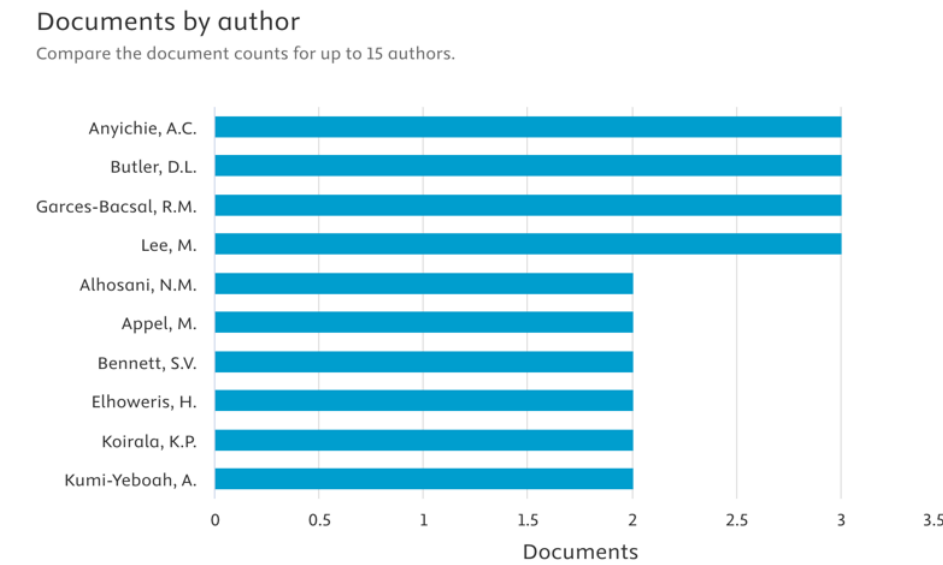
[Compare sources and view CiteScore, SJR, and SNIP data](#)



Source: Scopus Database

Figure 6. Number of Articles by Source (Top 10 Sources)

The fourth dimension of the analysis concerns the distribution of publications by author. Based on the top 10 contributing authors, the data show that Anyichie and Butler (2023), Butler and Lupton (2024); Garces-Bacsal et al. (2025); Lee and Mo (2023) published three articles each on the topic. In addition, Appel and Lee (2023), Bennett et al. (2018), Koirala (2023), and Kumi-Yeboah and Amponsah (2023) each produced 2 publications (see Figure 7).

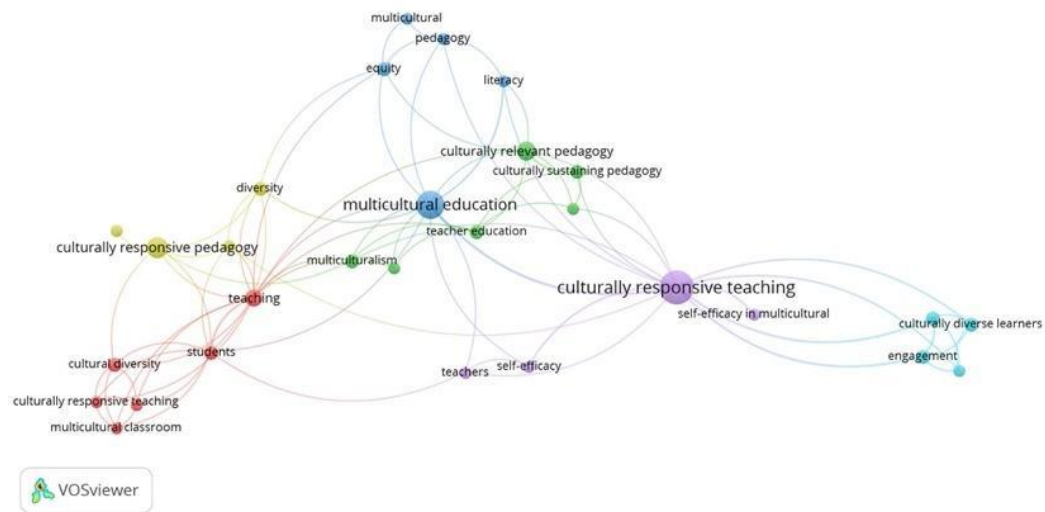


Source: Scopus Database

Figure 7. Count of Publications by Author (Top 10 Authors)

Theoretical and Practical Implications for the Development of CRT Research in Writing Instruction in Multicultural Classrooms

This study examined 73 articles retrieved from the Scopus database. Using VOSviewer, the analysis demonstrated that the existing body of research offers both theoretical and practical contributions to the development of Culturally Responsive Teaching (CRT) in writing instruction within multicultural classroom contexts. The bibliometric mapping identified key variables that have received substantial scholarly attention, as well as areas that remain underexplored. These findings provide a foundation for determining future research directions. The frequency and distribution of research topics are presented in Figure 8 and Table 1.



Source: VOSviewer Output

Figure 8. Co-Occurrence Framework and Representation of Key Terms

Table 1. Author-Provided Keywords and Total Link Strength

Rank	Keyword	Total Link Strength
1	Culturally Responsive Teaching	29
2	Multicultural Education	19
3	Teaching	18
4	Students	13
5	Culturally Relevant Pedagogy	10
6	Engagement	10
7	Self-Regulated Learning	10
8	Culturally Responsive Pedagogy	8
9	Diversity	8
10	Teacher Education	8

Source: VOSviewer Output

The keyword mapping generated through VOSviewer indicates that *culturally responsive teaching* occupies the most central position within the conceptual network, evidenced by its highest total link strength (TLS = 29), followed by *multicultural education* (TLS = 19) and *teaching* (TLS = 18). This dominant position suggests that CRT functions as a theoretical anchor that connects various pedagogical approaches, multicultural dimensions, and learning emphases within the analysed body of research. The structure of the network further demonstrates that CRT scholarship has evolved into a multidimensional field that integrates issues related to culture, pedagogical quality, and the development of student identity in multicultural learning contexts. The analysis also highlights several research gaps, particularly concerning the relationship between CRT and writing skill performance, the scarcity of longitudinal investigations, and the limited number of comparative studies across different educational settings. Overall, the mapping results confirm the pivotal role of CRT within the existing

literature and offer clearer directions for future research, especially studies focusing on literacy development and writing proficiency in diverse classroom environments.

Existing scholarship conceptualises Culturally Responsive Teaching (CRT) as a pedagogical framework that underscores the importance of recognising students' cultural backgrounds, linguistic repertoires, and individual abilities to enhance learning outcomes in a culturally supportive and student-centred manner (Bayraklı, 2026b; Idrus & Sohidi, 2023; Subasi Singh & Akar, 2021). CRT is grounded in three core principles: establishing equitable academic expectations for all learners supported by appropriate scaffolding; integrating students' cultural knowledge and lived experiences through culturally relevant curricula; and fostering critical awareness of power dynamics embedded within educational practices (Okilwa et al., 2025; Theeuwes et al., 2025). The principles provide a pedagogical foundation that enables teachers to design inclusive and adaptive classrooms for diverse student populations. The findings of this study further show that writing skills play a meaningful role in multicultural classroom settings. Such classrooms can serve as interactive spaces where students exchange perspectives, values, and intercultural experiences (Kaplan Toren & Schwartz, 2025; S. Lee et al., 2025). Incorporating multicultural perspectives into instructional methods is therefore essential for nurturing cross-cultural understanding and fostering mutual respect among learners (Cruz et al., 2025). A holistic understanding of these dynamics enhances the capacity of educational systems to create inclusive and representative learning environments for all students.

Conclusion

This systematic review provides a comprehensive overview of the conceptual and empirical developments concerning Culturally Responsive Teaching (CRT) in writing instruction within multicultural classroom settings. The evidence demonstrates that CRT contributes significantly to students' conceptual understanding and writing performance in culturally diverse contexts. The findings highlight that CRT facilitates writing instruction that addresses cognitive, affective, and socio-cultural dimensions of learning. Enhancing teachers' competence in creating culturally responsive learning environments is essential for the effective implementation of CRT in practice. Furthermore, the study underscores opportunities for future research, including the development of context-specific CRT models, the integration of digital tools in multicultural writing instruction, and the exploration of adaptive pedagogical strategies to meet the diverse needs of students in the 21st-century global educational landscape.

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CORRELATION BETWEEN LINGUISTIC INTELLIGENCE AND CRITICAL THINKING SKILLS IN SOLVING MATHEMATICAL PROBLEM ON MATRIX ALGEBRA

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Received: 23 October 2025; Accepted: * December 2025

Abstract

This study aims to investigate the correlation between linguistic intelligence in Indonesian and critical mathematical thinking in solving contextual problems. This study used a mixed methods approach, involving data from 204 eleventh-grade students at SMA Catholic St. Louis 1 Surabaya. A convergent parallel design was applied, with separate analyses conducted for quantitative and qualitative data. Quantitative data were analyzed using descriptive statistics and Pearson Correlation tests to determine the relationship between linguistic intelligence and mathematical problem-solving ability. Qualitative data were analyzed thematically following the Miles and Huberman framework. Findings from both analyses were integrated through triangulation techniques to produce accurate and comprehensive interpretations. Results show that 30% of students demonstrated conceptual thinking, 14.5% semi-contextual thinking, and 55.5% computational thinking. Students' linguistic abilities can be associated with six core components of critical thinking: interpretation, analysis, inference, evaluation, explanation, and self-regulation. Out of a total of 204 students, the average achievement for each component was 27.21% (interpretation), 20.59% (analysis), 21.32% (inference), 22.06% (evaluation), 20.59% (explanation), and 27.94% (self-regulation). This finding indicates that linguistic contributions can influence how students solve contextual problems. Furthermore, linguistic intelligence and mathematical intelligence exhibit a linear relationship, where individuals with high linguistic intelligence tend to have high logical thinking skills. Overall, these findings can help provide several practical implications for adapting problem-solving skills and effective teaching/learning.

Keywords: critical thinking, linguistic intelligence, mathematics, problem-solving

Introduction

Numeracy is the ability to use mathematics in modern life. This includes understanding mathematical meaning as it is expressed in language, symbols, and images (Clarke, 2024). Clarke also tells us that mathematics tasks require elaborate language comprehension in terms of textualization, contextualization, and discourse. This process requires a level of linguistic competence, commonly referred to as linguistic intelligence.



The ability to parse complex text is the first barrier to successful problem-solving. Strong reading comprehension skills allow students to identify relevant information, disregard distractors, and understand the logical structure of a problem statement. Research confirms that general reading ability is a powerful predictor of performance on mathematical word problems, even after controlling for calculation skills (Boonen et al., 2016). This is not merely about vocabulary; it is about the deep comprehension of syntax and semantics in a mathematical context. The process of explaining one's reasoning is now recognized as a critical component of learning. When students articulate their solution paths, they engage in metacognition, solidifying their own understanding and identifying gaps in their logic. Studies show that classroom practices emphasizing mathematical discourse where students explain, justify, and debate ideas lead to significant gains in conceptual understanding (Webb et al., 2019). This practice directly leverages linguistic skills in rhetoric and explanation.

Building on earlier theories, current research uses the concept of to describe how students use language, gestures, and other symbols dynamically to construct mathematical meaning. Nuñez et al. (2019) elaborate on how gesture is not merely an add-on but is co-constitutive of mathematical thinking, often conveying spatial and logical relationships that students cannot yet express formally. This multimodal communication is a direct application of a broader, more embodied form of linguistic intelligence.

The critical role of language makes linguistic demands a central equity issue. The academic language of mathematics can function as a "hidden curriculum" that disadvantages students who are still developing academic language proficiency, including English Learners. Innovative pedagogical approaches, such as encouraging students to use their full linguistic repertoire (translanguaging), are being shown to support deeper mathematical reasoning and inclusive participation in multilingual classrooms (Planas & Civil, 2021).

Mathematics is often described as a universal language; however, in practice, its learning process must be accompanied by linguistic skills, in this context, specifically the Indonesian language. Linguistic intelligence in the Indonesian language plays an important role in solving mathematical word problems. Septyaningsih (2018) states that solving mathematical word problems requires at least linguistic intelligence and logical-mathematical intelligence. Since the implementation of the 2013 Curriculum up to the current National Curriculum, mathematics instruction has increasingly emphasized problem-solving based on real-life or contextual issues. As a result, many students, particularly those in grade XI, still face difficulties in mapping out solutions to word problems.

The thinking process influences how students solve problems presented by the teacher (Miladia & Khabibah, 2018). An effective thinking process enables students to comprehend information, analyze problems, and determine appropriate problem-solving strategies. Thus, the quality of the thinking process significantly affects students' success in finding logical and effective solutions to the problems they encounter. This is consistent with the view of Nabilah and Lestari (2025), who state that systematic and reflective thinking skills serve as a crucial foundation in connecting linguistic understanding with mathematical problem-solving abilities. Moreover, linguistic intelligence assists students in interpreting the meaning of

contextual problems, allowing them to transform verbal information into accurate mathematical representations.

The urgency of this research lies in the need to examine the interrelationship between linguistic competence in the Indonesian language and high school students' critical thinking skills in solving context-based mathematical problems. This study aligns with the demands of 21st-century learning, which emphasizes language literacy, critical thinking, and integrated, comprehensive problem-solving. Numerical literacy refers to the knowledge and skills required to use various numbers and symbols related to basic mathematics to solve real-world problems in everyday life (Rosalia & Suhardi, 2020). Therefore, this research is expected to strengthen the understanding of the importance of language proficiency as an integral component of mathematical thinking processes, while also serving as a practical reference for teachers in designing learning activities that foster the integration of linguistic and logical-mathematical aspects.

SMA Katolik St. Louis 1 Surabaya was selected as the research site due to its strong reputation for students with high proficiency in both language and mathematics. Strong linguistic ability enables students to comprehend the meaning and context of problems more accurately, while excellent mathematical competence supports the application of logical reasoning in problem-solving. The combination of these two abilities makes this school an ideal setting to investigate the correlation between linguistic intelligence and critical thinking skills in solving context-based mathematical problems.

Building on the previous study conducted by Indaswari et al. (2021), it is evident that both types of intelligence significantly affect students' ability to comprehend problem contexts and determine appropriate solution strategies. This consistency is also reflected in research conducted at SMA Negeri 1 Batukliang Utara, which found that logical-mathematical intelligence shows a strong correlation (0.786) and contributes 61.7% to students' word-problem-solving performance, while linguistic intelligence likewise demonstrates a significant influence with a strong correlation (0.753). When combined, both intelligences exhibit a very strong relationship (0.810) in enhancing students' ability to solve word problems, particularly in linear programming. Overall, these studies reaffirm that students' success in solving word problems is shaped not only by numerical or computational skills but also by their capacity to understand language and process information logically.

In the process of solving contextual mathematical problems based on word questions, a method is required to model the problem into mathematical language, commonly referred to as a mathematical model. Mathematics is an abstract science that focuses on reasoning ability (Ekasari, 2014). Mathematical modelling is a field of mathematics used to represent and explain physical systems or problems in mathematical statements. The mathematical representation resulting from this process is known as a mathematical model. Forming, analyzing, and using mathematical models is one of the mathematics applications that can represent life problems into mathematical statements (Haryanto et al., 2015)

According to the OECD (2022), on average across OECD countries, more students performed at proficiency Levels 2 (23%) and 3 (22%) than at Level 4 (15%) in mathematics. Furthermore, only a small proportion of students scored at level 5 (7%) and Level 6 (2%) on average across OECD countries, and in reading,

more students performed at proficiency level 2 (24%) and level 3 (25%) than at level 4 (17%) on average across OECD countries. Moreover, only a small proportion of students scored at Level 5 (6%) and Level 6 (1%) on average across OECD countries.

Proficiency in mathematics is closely tied to language and reading abilities. This is supported by Peng et al. (2020), who found that language is significantly and moderately associated with mathematics, with a stronger relation observed for more complex language and mathematics skills. This connection is largely because language serves as the primary medium for accessing mathematical problems, student must first decode and comprehend a word problem's text before they can even begin to solve it mathematically (Boonen et al., 2016). Furthermore, this relationship is not merely about vocabulary but extends to greater metalinguistic skill, such as the ability to understand syntactic structures and logical connectors. These are essential for parsing the complex cause-and-effect relationship often present in mathematical reasoning. Consequently, challenges in reading comprehension can create an artificial barrier to mathematical achievement, meaning a student's difficulty may lie not in their calculation skill, but in their ability to interpret the linguistic framing of the task itself.

Essentially, language ability enables students to understand the terms, sentence structures, and conceptual relationships that appear in mathematics problems. This allows them to grasp the intent of a question more accurately. Difficulties in mathematics are often not rooted in computation, but rather in an inability to interpret instructions or filter relevant linguistic information. Therefore, literacy competencies from understanding key words and identifying main premises to inferring relationships between ideas serve as an entry point to deeper mathematical understanding.

In addition, linguistic development helps sharpen metacognitive abilities such as critical thinking and providing justification for answers. These skills are crucial for solving higher-order problems. They encourage students not only to produce an answer but also to understand why a particular procedure is used.

Peng et al.'s (2020) findings show that the more complex the language structures students can comprehend, the better they manage mathematical concepts that require abstract reasoning. Thus, it reinforces the idea that improving literacy cannot be separated from enhancing mathematical ability. Integrating language learning into mathematics instruction becomes an essential strategy for maximizing the development of both domains simultaneously

The process of critical thinking in mathematics is used to solve more contextual problems or those involving higher-order thinking skills (HOTS) questions. Therefore, Facione (2015) in his journal explains that the essence of critical thinking skills is:

“As to the cognitive skills, here is what the experts include as being at the very core of critical thinking: interpretation, analysis, evaluation, inference, explanation, and self-regulation.”

Accordingly, Facione presents these components in the following table.

Table 1. Indicator of Critical Thinking (Facione, 2015)

Core Critical Thinking Skills		
SKILL	Experts' Consensus Description	Subskill
Interpretation	"To comprehend and express the meaning or significance of a wide variety of experiences, situations, data, events, judgments, conventions, beliefs, rules, procedures, or criteria"	Categorize Decode significance Clarify meaning
Analysis	"To identify the intended and actual inferential relationships among statements, questions, concepts, descriptions, or other forms of representation intended to express belief, judgment, experiences, reasons, information, or opinions"	Examine ideas Identify arguments Identify reasons and claims
Inference	"To identify and secure elements needed to draw reasonable conclusions; to form conjectures and hypotheses; to consider relevant information and to reduce the consequences flowing from data, statements, principles, evidence, judgments, beliefs, opinions, concepts, descriptions, questions, or other forms of representation"	Query evidence Conjecture alternatives Draw logically valid or justified conclusions
Evaluation	"To assess the credibility of statements or other representations that are accounts or descriptions of a person's perception, experience, situation, judgment, belief, or opinion; and to assess the logical strength of the actual or intended inferential relationships among statements, descriptions, questions, or other forms of representation"	Assess credibility of claims Assess quality of arguments that were made using inductive or deductive reasoning
Explanation	"To state and to justify that reasoning in terms of the evidential, conceptual, methodological, criteriological, and contextual considerations upon which one's results were based; and to present one's reasoning in the form of cogent arguments"	State results Justify procedures Present arguments
Self-Regulation	"Self-consciously to monitor one's cognitive activities, the elements used in those activities, and the results educed, particularly by applying skills in analysis, and evaluation to one's own inferential judgments with a view toward questioning, confirming, validating, or correcting either one's reasoning or one's results"	Self-monitor Self-correct

The challenges highlighted by the PISA results, coupled with common issues observed in mathematics classrooms, necessitate research into the linguistic features of contextual mathematical word problems. Such problems are often central to pedagogical approaches involving deep learning. The goal of deep learning is that students will gain the competencies and dispositions that will prepare them to be creative, connected, and collaborative (Fullan & Langworthy, 2013).

This study is limited to Grade XI students in the subject of matrices. This study aims to investigate:

1. What is the contribution of Indonesian linguistic intelligence to the mathematical problem-solving ability of Grade XI students at SMAK St Louis 1 Surabaya in solving contextual word problems
2. How is the correlation between linguistic and the critical thinking skill of Grade XI students at SMAK St Louis 1 Surabaya in solving mathematical word problems?

Method

This study utilizes a mixed-methods approach, based on the National Institute of Health (NIH) (2018), mixed-methods involve both quantitative and qualitative data throughout research endeavors. A mixed methods approach allows researchers to use a diversity of methods combining inductive and deductive thinking, and offsetting limitation of exclusive quantitative and qualitative research through a complementary approach that maximize strength of each data (Harvard Catalyst 2018). The primary rationale for this design is to acquire a comprehensive and in-depth perspective on the contribution of linguistic intelligence to mathematical problem-solving skills.

We use seven steps based on Creswell (2022) in the process of mixed methods research, namely

1. Draft a working title for the project
2. Write about the research problem and shape it toward mixed methods
3. State the general question, aim, or objective of the study
4. Consider whether to include a worldview and a theory
5. Detail the methods section
6. Consider how meta-inferences will be drawn from integration, and
7. Revisit your question, aims, or objectives.

The study began with formulating a working title that clearly represented its central focus: the relationship between linguistic intelligence and students' critical mathematical thinking in solving contextual problems. The researcher then identified issues related to variations in students' mathematical thinking skills and the potential influence of linguistic intelligence, which justified the use of a mixed-methods approach to obtain a more comprehensive understanding. The research objectives were subsequently articulated to examine the association between the two variables and to explore how linguistic intelligence contributes to students' critical thinking processes.

A pragmatic worldview was adopted to support the integration of quantitative and qualitative data, underpinned by the theories of multiple intelligences, critical thinking, and problem-solving. The study employed a convergent parallel design, combining descriptive statistics and Pearson correlation analyses for the quantitative strand with Miles and Huberman's thematic analysis for the qualitative strand. Findings from both components were integrated through triangulation to generate meta-inferences that synthesized numerical results with qualitative insights. In the final phase, the researcher revisited the research questions and objectives to ensure that the integrated findings effectively addressed the study's focus while offering theoretical contributions and practical implications for the development of instructional strategies

The research methodology for this study is a convergent parallel design. Quantitative and qualitative data were gathered concurrently from 204 participants in the eleventh grade. The analysis will involve examining the student's solution and their accompanying expositions through a set of rigorously defined indicators.

This study employs a separate analysis for quantitative and qualitative data. The purpose of using a mixed-method approach is to obtain a more comprehensive understanding by utilizing the strengths of both approaches, allowing researchers to explore phenomena in depth while also measuring and testing variables statistically (Nurfajriani et al., 2024). The collected data will subsequently be

compared and analyzed using pre-established indicators to derive conclusions. Quantitative research can be used to fill the gaps that emerge in qualitative studies, Mustaqim (2016). The quantitative data analysis will be conducted using descriptive statistics to provide an overview of data trends and inferential statistics employing Pearson correlation tests to examine the relationship between linguistic intelligence and mathematical problem-solving ability. The qualitative data will be analyzed using thematic analysis following the Miles and Huberman model, which encompasses data reduction, data display, and conclusion drawing (Wijaya, 2018). Subsequently, the results from both analytical approaches will be integrated using triangulation techniques to compare and connect findings from both quantitative and qualitative approaches, ensuring an interpreted, accurate, and comprehensive understanding. Triangulation, in essence, is a multi-method approach employed by researchers when conducting research, collecting, and analyzing data. (Nurfajriani et al., 2024)

The problems given in this study are

Problem 1: Nutritional Data (Table & Matrix Representation)

This problem assesses the fundamental skill of translating real-world quantitative information into structured mathematical formats.

a. Data Organization and Tabulation

Indicator: Students are able to systematically organize multivariate data (age, activity level, caloric intake) into a clear and logical tabular format. Specific Skills: Identifying the relevant variables from a descriptive text. Deciding on a logical structure for the table (e.g., choosing rows for age groups and columns for activity levels, or vice-versa). Presenting the data accurately without omission or error.

b. Abstraction into Mathematical Models

Indicator: Students are able to abstract numerical data from a table and represent it as a mathematical matrix, understanding the structure of rows and columns. Specific Skills: Distinguishing between the data in a table and the structure of a matrix. Writing a matrix correctly using bracket notation. Articulating what the rows and columns of their matrix represent in the context of the problem (e.g., "Row 1 represents the caloric needs for ages 11-12," and "Column 3 represents the needs for 2 hours of training").

c. Mathematical Communication and Flexibility

Indicator: Students are able to compare different mathematical representations of the same data and understand that the structure (e.g., transposition) can vary while the information content remains the same.

Specific Skills:

Engaging in discussion about different possible matrix structures (e.g., Is the age group the row or the column?). Recognizing that a matrix and its transpose are both valid representations of the same dataset. Explaining how the context might influence the choice of representation.

Problem 2: Chip Inventory (Matrix Operations and Application)

This problem assesses the ability to use matrices not just for representation, but for performing meaningful operations that solve a real-world problem.

- a. **Contextual Matrix Construction**
Indicator: Students are able to construct multiple matrices/vectors from a single contextual problem.
Specific Skills:
Creating a matrix (I) (inventory) from tabular data, where rows represent stores and columns represent products.
Creating a column vector (P) (price) from a given list of values.
Ensuring the dimensions of the matrices are compatible for the intended operation.
- b. **Selection and Justification of Matrix Operations**
Indicator: Students are able to identify the appropriate matrix operation that models a given real-world scenario. Specific Skills:
Recognizing that matrix multiplication $(I \times P)$ is the operation that corresponds to calculating the total (revenue) for each entity (store).
Justifying why this operation is chosen over others (e.g., addition or subtraction is not meaningful here). Understanding the condition for matrix multiplication (the number of columns in the first matrix must equal the number of rows in the second).
- c. **Computational Skill and Interpretation**
Indicator: Students are able to accurately perform matrix multiplication and interpret the resulting vector within the context of the problem.
Specific Skills:
Correctly executing the algorithm for matrix multiplication. Stating clearly what each entry in the resulting vector represents (e.g., "The first element of the result is the total revenue for Store A"). Connecting the abstract mathematical result back to the original business context.

Findings and Discussion

To analyze the contribution of Indonesian linguistic intelligence to mathematical problem-solving ability, this study adopts the indicators proposed by Nugroho (2013), which are outlined below.

Table 2. Indicators of Indonesian Linguistic Intelligence
Adapted from Nugroho (2013)

Conceptual Thinking Process	Semi-Conceptual Thinking Process	Computational Thinking Process
Able to write or explain what is known in the problem using their own words or transform it into a mathematical statement.	Less able to write or explain what is known in the problem using their own words or transform it into a mathematical statement.	Unable to write or explain what is known in the problem using their own words or transform it into a mathematical statement.
Able to write or explain what is asked in the problem using their own words or transform it into a mathematical statement.	Less able to write or explain what is asked in the problem using their own words or transform it into a mathematical statement.	Unable to write or explain what is asked in the problem using their own words or transform it into a mathematical statement.

Able to write or explain the learned concepts that will be used to solve the problem.	Less able to write or explain the learned concepts that will be used to solve the problem.	Unable to write or explain the learned concepts that will be used to solve the problem.
Able to write or explain the steps taken to solve the problem using the learned concepts.	Less able to write or explain the steps taken to solve the problem using the learned concepts.	Unable to write or explain the steps taken to solve the problem using the learned concepts.

The application of the indicator revealed the following distribution of students' thinking categories: in problem 1, 32.12% of students demonstrated conceptual thinking, 16,20% exhibited semi-conceptual thinking, and the majority, 51,67%, employed computational thinking. problems 2, 27.95% of students demonstrated conceptual thinking, 12.78% exhibited semi-conceptual thinking, and the majority, 59.27%, employed computational thinking.

Rahardi (2024) argues that language functions as a medium to initiate, develop, and strengthen harmonious relationships between linguistics and mathematics, which has a significant influence on the comprehension of word problems in problem solving. The following indicators are presented based on Chomsky's theory (1981), which relates to the contribution of Indonesian linguistic intelligence to students' problem-solving skills and mathematical performance among eleventh-grade students of SMAK St. Louis 1 Surabaya.

Table 3. Linguistic Intelligence Indicator Developed from Chomsky (1981)

Indicator	Point 1	Point 2	Point 3	Point 4
Ability to understand the sentence structure in mathematical word problems	The student can identify the basic grammatical elements within a mathematical word problem.	The student can examine the logical relationships among sentences in the problem text.	The student can interpret the meaning of sentence structures logically in a mathematical context.	The student can comprehensively understand the overall sentence structure and relate it to the mathematical context of the problem.
Ability to present written explanations of mathematical solutions clearly	The student can write basic solution steps based on an understanding of the problem.	The student can express explanations in their own words in a clear and sequential manner.	The student can construct written mathematical explanations with coherent and logical reasoning.	The student can present comprehensive and well-structured written mathematical explanations supported by logical arguments.

Ability to paraphrase mathematical word problems into mathematical models	The student can restate part of the problem information using simple mathematical symbols.	The student can reformulate the problem statement to show relationships between variables.	The student can translate all relevant information from the problem into an appropriate mathematical model.	The student can interpret and formulate the word problem accurately and efficiently into mathematical equations or expressions.
Ability to construct various forms of mathematical explanations or answers	The student can create a simple form of explanation based on calculation results.	The student can compose alternative sentences to explain problem-solving steps.	The student can construct logical and contextually relevant explanatory sentences.	The student can produce effective, communicative, and mathematically accurate explanatory sentences.
Ability to develop an intuitive understanding related to the meaning of mathematical problems with varied sentence structures	The student can recognize differences in sentence structures across similar mathematical problems.	The student can accurately interpret the meaning of differently structured sentences.	The student can adjust their understanding according to variations in sentence structure within mathematical problems.	The student can comprehend and explain the meaning of problems with complex and varied sentence structures accurately.
Ability to identify key and essential elements in mathematical problem texts based on sentence patterns	The student can identify key words or main information in the problem text.	The student can highlight essential elements and understand their grammatical roles in the sentence.	The student can analyze the relationships among key elements within the sentence structure of the problem.	The student can identify, connect, and utilize key elements to accurately understand the overall meaning of the mathematical problem.

Based on the analysis of students' written responses to the first problem, the following percentage achievements for each linguistic intelligence indicator were obtained: understanding question sentence structure (22.37%), explaining mathematical solutions (22.37%), paraphrasing questions into mathematical models (11.84%), creating varied explanatory sentences (10.53%), developing intuitive understanding of the problem's meaning (9.21%), and identifying key elements in the problem text (14.47%).

For the second problem, the percentage achievements were: understanding question sentence structure (19.74%), explaining mathematical solutions (22.37%), paraphrasing questions into mathematical models (11.84%), creating varied explanatory sentences (14.47%), developing intuitive understanding of the problem's meaning (18.42%), and identifying key elements in the problem text (13.16%).

Guided by a framework integrating Noam Chomsky's theory of linguistic structure with core critical thinking components, our analysis of 204 students' mathematical problem-solving reveals a distinct cognitive profile. The data indicate that students' primary strengths are metacognitive and interpretative. The highest demonstrated skill was Self-regulation (27.94%), defined as the ability to identify key elements in problem text based on sentence patterns, suggesting a proficiency in monitoring one's own engagement with the linguistic structure of problems. This was closely followed by Interpretation (27.21%), reflected in the capacity to understand sentence structure within word problems. However, the application of deeper analytical processes shows a relative decline. Skills such as Inference (21.32%) able to paraphrase word problems into mathematical models, and Evaluation (22.06%), which are able to construct varied explanations or answer clusters with Analysis (20.59%) and Explanation (20.59%), which involve explaining solutions in writing and developing an intuitive understanding. This pattern suggests that while students are adept at the initial, structurally-focused stages of problem-solving (decoding and self-monitoring), they encounter a shared challenge in fluently executing the transformative and communicative acts of analysis, synthesis, and justification, pointing toward a critical area for targeted pedagogical intervention

Discussion

A significant relationship between linguistic intelligence and Critical Thinking skills indicates that an increase in one is associated with an enhancement in the other, and vice versa. This interdependence is particularly crucial in mathematics problem-solving.

Recent research substantiates this connection. Darwis et al. (2024) posit that linguistic intelligence aids students in developing mathematical communication skills, which are fundamental for articulating solution pathways. Similarly, Atmojo et al. (2024) identified a significant correlation between linguistic intelligence and computational thinking, a key component of modern problem-solving. Their study specified that among various linguistic indicators, rhetoric (structured argumentation), explanation (clarifying processes), and metalinguistics (the ability to reflect on language use) are strongly linked to computational thinking abilities. Consequently, they recommend fostering these specific skills to enhance students' computational thinking.

To fully appreciate this relationship, it is essential to understand language's multifaceted role in mathematics learning. Planas and Pimm (2023) provide a robust framework through four key concepts: instructional designing (crafting language-aware lessons), gesturing (using physical movement to embody mathematical ideas), arguing (constructing logical cases), and languaging (the active process of using language to construct meaning). These concepts collectively

outline the kind of learning environment necessary to bridge language and mathematical understanding.

However, the implementation of this ideal is challenging. The struggle to integrate everyday language with the precise language of mathematics is a global issue in education. As noted by Ingram, Abbott, and Smith et al., both teachers and students often face difficulties when appropriate analogies are missing or when the practical function of mathematics remains abstract and disconnected. This "language struggle" is a pervasive problem that can significantly hinder mathematical comprehension if not addressed.

While the findings confirming the correlation between linguistic intelligence and mathematical problem-solving are compelling, several limitations must be acknowledged. First, the sample size of this study was relatively small and restricted to eleventh-grade students, limiting its generalizability. A larger and more diverse sample would provide a more comprehensive understanding. Second, the instruments used to measure the core constructs could be refined for greater validity and reliability. Finally, the cross-sectional design of this study only captures a single moment in time. For a deeper exploration of how this relationship evolves, longitudinal studies are necessary.

In conclusion, this discussion underscores the powerful synergy between linguistic intelligence and mathematical problem-solving while opening avenues for future research. Addressing the noted limitations through larger-scale, longitudinal, and methodologically diverse studies will allow for a more complete capture of this critical dynamic in education.

Compared with earlier conceptualizations, the study conducted by Indaswari et al. (2021) demonstrated that both mathematical logical intelligence and linguistic intelligence exert strong and significant contributions to students' ability to solve word problems. Mathematical logical intelligence showed a high correlation (0.786) with an effect size of 61.7%, while linguistic intelligence also exhibited a strong correlation (0.753). Collectively, these two domains yielded a very strong correlation (0.810) with improvements in students' problem-solving performance. These findings confirm that higher levels of logical and linguistic intelligence are directly proportional to the quality of students' solutions to word problems.

In contrast, the present study provides a more nuanced account of how specific components of linguistic intelligence operate within the mathematical problem-solving process. Analysis of students' written responses reveals uneven mastery across linguistic indicators. Students demonstrated the highest levels of achievement in understanding sentence structure and explaining mathematical solutions (20–22%), whereas the ability to construct varied explanatory statements was substantially lower (10–14%). When examined through the lens of a critical-thinking framework, students performed strongest in self-regulation and interpretation (approximately 27%), yet showed consistent weaknesses in inference, evaluation, analysis, and explanation, each ranging only from 20–22%. Moreover, most students continued to rely predominantly on computational thinking (51–59%) rather than conceptual thinking.

Accordingly, while the findings of Indaswari et al. (2021) underscored the positive influence of linguistic intelligence on problem solving, the present study extends this understanding by revealing that such contributions are not evenly distributed across linguistic components. Students tend to demonstrate competence

in the initial stages of linguistic processing but encounter considerable difficulty in more advanced analytical processes and in transforming linguistic information into mathematical models. Thus, this study not only reinforces previous evidence but also identifies specific aspects of linguistic intelligence that remain underutilized by students in solving mathematical word problems.

Conclusion

The findings of this study indicate that the majority of students demonstrate computational thinking, with considerably smaller proportions exhibiting conceptual and semi-conceptual thinking across both problems analyzed. The mapping grounded in Chomsky's linguistic theory and Facione's critical thinking framework further reveals that students' linguistic abilities are strongly associated with the six core components of critical thinking, with the highest levels of achievement shown in interpretation and self-regulation. These results confirm that Indonesian linguistic intelligence plays a significant role in enhancing students' mathematical problem-solving abilities, particularly in comprehending the context of word problems and regulating cognitive processes more reflectively. Overall, linguistic intelligence serves as an essential factor in strengthening the reasoning, evaluation, and mathematical meaning-making of Grade XI students at SMAK St. Louis 1 Surabaya.

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THE IMPACT OF GADGET USE ON ADOLESCENTS' SLEEP QUALITY

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Received: 1 November 2025; Accepted: 12 December 2025

Abstract

The intensive use of gadgets among adolescents is strongly suspected to be a major factor contributing to the decline in sleep quality. This study aims to analyze the correlation between the duration of gadget use at night and adolescents' sleep quality. The method employed is a literature review of relevant scientific journals. Data analysis was conducted qualitatively using a thematic synthesis technique to identify patterns and relationships between variables from existing findings. The results reveal a consistent positive relationship between the intensity of gadget use, particularly during pre-sleep hours, and the decrease in adolescents' sleep quality and duration. Psychostimulant content, such as social media and online games, significantly contributes to heightened cognitive arousal (hyperarousal) and anxiety, which further hinders adolescents from falling asleep. It is concluded that excessive gadget use negatively affects adolescents' sleep through two primary mechanisms: the inhibition of melatonin production by blue light and the increase in cognitive arousal caused by digital content.

Keywords: adolescents, blue light, gadget use, hyperarousal, sleep quality

Introduction

Over the past decade, advancements in digital technology have significantly altered adolescent lifestyles, embedding devices into the very fabric of daily routines (Twenge, 2017). Computers, tablets, and smartphones have become essential tools for learning, communication, and entertainment. However, despite their utility, excessive use, particularly before bedtime, disrupts adolescents' circadian rhythms and sleep quality. Research indicates that approximately 90% of adolescents use electronic devices at least one hour before sleep, which is associated with reduced sleep duration and total sleep time (Hysing et al., 2015). Blue light emitted by digital screens has the biological potential to suppress melatonin, a hormone that regulates sleep-wake cycles (Cajochen et al., 2011). Even brief exposure to blue light at night can shift circadian phases and prolong sleep latency, a finding supported by controlled laboratory studies (Wood et al., 2013).

Beyond physiological effects, the interactive and emotionally charged nature of digital content can lead to cognitive hyperarousal, characterized by increased mental and emotional activity that impedes pre-sleep relaxation (Exelmans & Van den Bulck, 2016). This condition causes adolescents to experience difficulty sleeping. Adolescents are particularly vulnerable due to a natural tendency towards delayed sleep phases, and gadget use exacerbates this propensity (Touitou et al., 2017). Furthermore, the constant need for social connectivity fosters a fear of



missing out (FoMO) and compulsive checking behaviors, both contributing to chronic sleep disturbances (Scott & Woods, 2018). The displacement of traditional pre-sleep activities by screen time further reduces the opportunity for wind-down routines (Bartel et al., 2015).

Therefore, this study aims to synthesize empirical findings on the impact of gadget use on adolescent sleep quality. It places particular emphasis on physiological and psychosocial components, as well as scientifically grounded preventive measures. Lifestyle changes driven by technological development not only affect how adolescents interact with the external world but also alter their daily patterns, including sleep activities. Dependence on gadgets creates new, hard-to-control habits, such as repeatedly checking messages or social media late into the night (Gradisar et al., 2013). Adolescents often feel social pressure to stay connected with peers, leading to increasingly shorter and poorer quality sleep (Vernon et al., 2018). This disrupts the body's physiological balance, which requires adequate rest for regeneration and energy recovery.

Poor sleep quality during adolescence can have broad implications for physical and psychological development. Sleep deprivation impairs concentration, reduces critical thinking abilities, and diminishes learning motivation (Dewald-Kaufmann et al., 2013). Furthermore, fatigue from insufficient sleep can trigger stress and increase the risk of emotional disorders such as irritability and anxiety (Lemola et al., 2015). Long-term, irregular sleep patterns can disrupt metabolism, weaken the immune system, and increase obesity risk (Cappuccio et al., 2008). Consequently, research on the relationship between gadget use and adolescent sleep quality is crucial for understanding the root of the problem and identifying realistic solutions. A systematic review and meta-analysis by Carter et al. (2016) confirms a strong association between access to or use of media devices and inadequate sleep quantity and quality.

This literature review seeks to fill a gap by synthesizing the most recent evidence and providing a holistic view that integrates findings from diverse cultural contexts, including Indonesia, to offer a more globally relevant perspective. Adolescents undergo significant neurological development that makes them particularly susceptible to sleep disruptions (Giedd, 2015). The delayed circadian rhythm typical of this age group, combined with early school start times, creates a perfect storm for sleep deprivation (Owens et al., 2014). When compounded by excessive gadget use, this biological predisposition can lead to severe consequences for cognitive development and mental health. The portability of modern devices means that sleep environments are no longer protected spaces for rest but have become extensions of the digital social world, blurring the boundaries between wakefulness and sleep (Exelmans & Van den Bulck, 2016). Importantly, emerging experimental research indicates that interventions targeting evening screen exposure can be effective, with studies showing that reducing screen time in the evening significantly improves sleep onset in adolescents.

Method

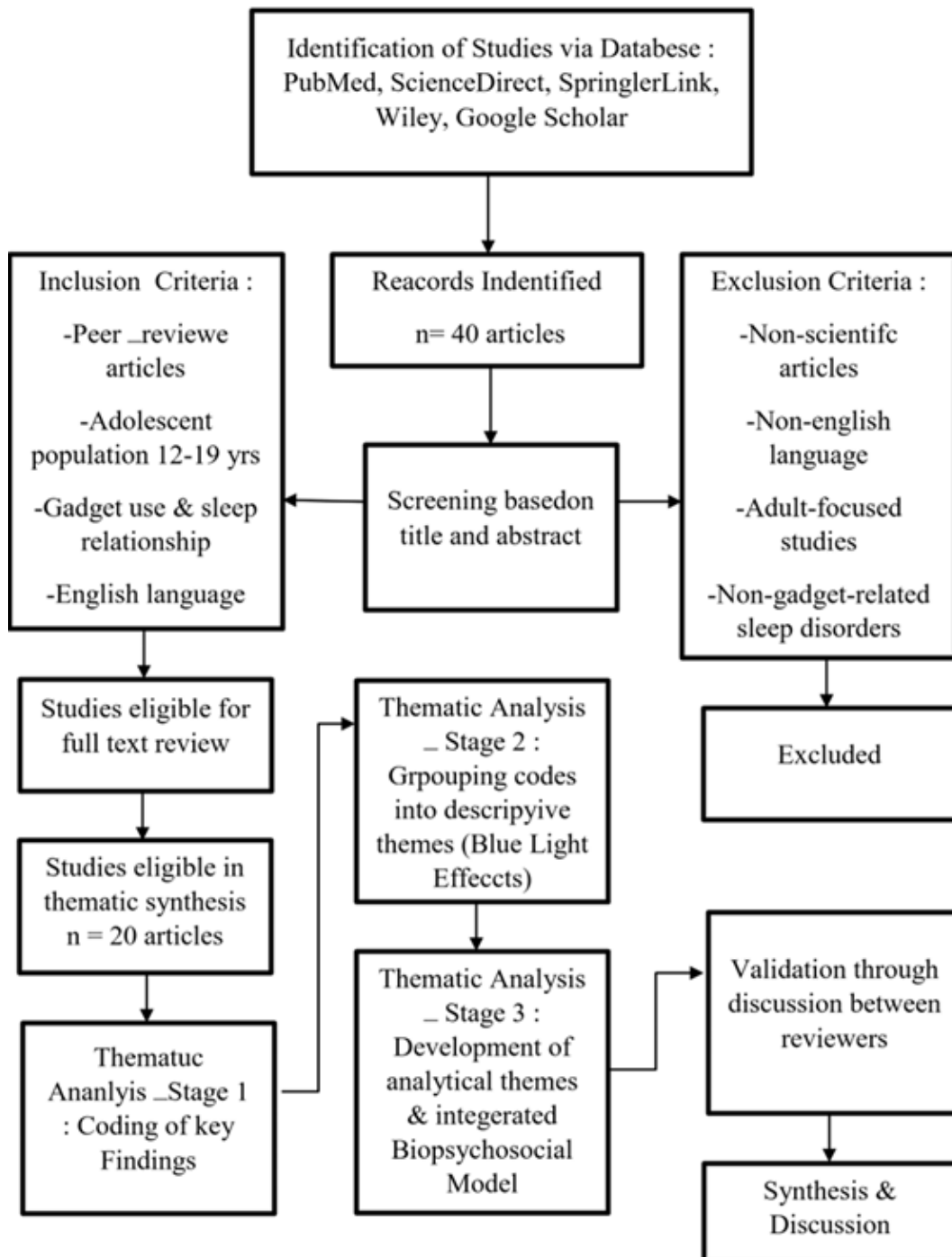


Figure 1. Methodology Flowchart

This research examines literature on the subject and integrates quantitative and qualitative findings from prominent international journals published between 2010 and 2025. The primary goal was to identify consistent themes, mechanisms, and patterns related to adolescent gadget use and sleep quality. Using a combination of keywords including "gadget use," "screen time," "mobile phone use," "sleep

disturbance," "melatonin," "blue light," "adolescent," and "teenager," article searches were conducted via PubMed, ScienceDirect, SpringerLink, Wiley Online Library, and Google Scholar databases.

Inclusion criteria consisted of peer-reviewed scientific articles focusing on adolescents aged 12 to 19 years that discussed the relationship between gadget use and sleep-related factors such as duration, latency, efficiency, or quality. Exclusion criteria encompassed non-scientific articles, articles not in English, and studies focusing on adults or sleep disorders unrelated to gadgets. Data from selected articles were analyzed thematically based on research design, sample size, sleep quality measurement tools, duration of gadget exposure, and main outcomes. The results were used to identify related patterns, biological and psychological mechanisms, and intervention methods.

In the literature review process, the authors selected approximately forty scientific articles relevant to the research topic. Of these, only twenty articles met the eligibility criteria based on their focus on adolescent populations, methodological clarity, and relevance of findings to the research variables. Each article was carefully analyzed to identify common themes and differing findings. A thematic approach was used to highlight recurring factors, such as pre-sleep gadget use duration, types of digital activities, and their impact on sleep quality.

Analysis was conducted stepwise by comparing findings across studies to identify general patterns. Validation was achieved through discussion between the two reviewers to enhance objectivity.

Although qualitative, this method provides a sufficiently clear picture of the relationship between the studied variables, even if it cannot directly establish causality. Furthermore, the thematic synthesis was conducted in three iterative stages: first, the coding of key findings from each article; second, the grouping of these codes into descriptive themes (e.g., "blue light effects," "social media anxiety"); and finally, the development of analytical themes that interpret and explain the relationships between these descriptive themes, leading to the integrated biopsychosocial model presented in the discussion.

To ensure methodological rigor, the quality of included studies was assessed using standardized critical appraisal tools. For cross-sectional studies, we evaluated sample representativeness, measurement validity, and appropriate statistical analysis. For experimental studies, we examined randomization procedures, blinding, and control of confounding variables. This quality assessment revealed that while most studies demonstrated strong methodological approaches, some relied exclusively on self-reported data for both gadget use and sleep outcomes, potentially introducing recall bias. Nevertheless, the consistency of findings across different methodological approaches strengthens the overall conclusions. The search strategy was also limited to articles published in English, which may have excluded relevant studies in other languages, though our inclusion of Indonesian research through English-language databases helped mitigate this limitation for the specific context of interest.

Findings and Discussion

This review synthesizes empirical evidence to examine the multifaceted relationship between gadget use and adolescent sleep quality. The findings are

organized thematically, addressing the strength of the association, underlying mechanisms, moderating factors, and potential interventions.

Dose-Response Relationship and Correlation Strength

Numerous studies indicate a strong correlation between the intensity of gadget use and poorer sleep quality, demonstrating a clear dose-response relationship. A long-term study in Norway found that adolescents using electronic devices for more than four hours daily had double the risk of insomnia (Hysing et al., 2015). This pattern is consistent across various studies, with evidence suggesting that for every additional hour of screen time beyond a baseline, adolescents experience a significant increase in the likelihood of developing clinical insomnia symptoms (Hale & Guan, 2015). The relationship demonstrates a non-linear trajectory, with the most severe sleep disturbances observed in heavy users, particularly when use extends into the pre-sleep period (Bartel et al., 2015). This threshold effect highlights critical intervention points, indicating that interventions targeting the heaviest users could yield the most significant public health benefits (Carter et al., 2016). Research conducted in Indonesia corroborates this global pattern, reporting that 84.8% of adolescents with high gadget usage experienced poor sleep quality (Ivana et al., 2021). The consistency of these findings across diverse methodologies strengthens the causal inference about screen time's detrimental role (Carter et al., 2016).

Physiological and Neurological Mechanisms

The biological pathways linking screen time to sleep disruption are well-established. Through retinal photoreceptors, exposure to blue light (wavelength 460–480 nm) suppresses melatonin secretion (Cajochen et al., 2011). Experimental research has demonstrated that evening blue light exposure increases alertness and delays sleep onset (Chang et al., 2015). Furthermore, reading from an e-reader before bed was found to reduce melatonin levels by up to fifty-five percent compared to reading a printed book, directly disrupting circadian rhythms (Touitou et al., 2017). This suppression is dose-dependent, with greater exposure leading to more pronounced delays in melatonin onset (Chang et al., 2015). Adolescent brains show heightened sensitivity to these effects, creating a neurodevelopmental susceptibility where technology use directly conflicts with biological sleep needs (Giedd, 2015).

Psychosocial and Behavioral Drivers

Beyond physiology, the interactive nature of digital content contributes to cognitive hyperarousal. Activities such as gaming or social media use heighten mental activation, impeding the relaxation necessary for sleep onset (Vernon et al., 2018). The Fear of Missing Out (FoMO) induces social anxiety, prompting adolescents to stay connected online, resulting in sleep fragmentation (Alt, 2015). This combination of psychological stimulation and biological disruption reinforces late-night habits within a biopsychosocial model (Gradisar et al., 2013). The type of content is a critical moderator; interactive activities like competitive gaming cause greater arousal than passive watching (King et al., 2013). Social media platforms, with their algorithmically curated feeds, exacerbate FoMO and an

"always-on" mentality, while online games create compelling social and reward-based pressures to delay sleep, effectively displacing sleep time.

Moderating Factors: Content, Context, and Culture

The impact of gadget use is not uniform but moderated by several factors. The type of digital activity plays a significant role, with interactive content being more detrimental than passive consumption (Bartel et al., 2015). Environmental and familial contexts are equally crucial. Adolescents with clear parental rules and supervision regarding gadget use demonstrate better sleep outcomes (Vernon et al., 2018). Conversely, a lack of control and parental modeling of poor digital habits normalizes disruptive behavior. Cross-cultural research reveals significant variations. In collectivist cultures like Indonesia, family interdependence may offer some protective oversight, while in individualistic Western societies, private device use in bedrooms leads to more pronounced disruptions (Scott & Woods, 2018). Demographic differences also emerge, with females showing greater vulnerability to social media-related sleep disturbances and males to impacts from gaming (Lemola et al., 2015). These moderating factors explain why universal screen time limits may be less effective than tailored interventions (Bartel et al., 2015).

Consequences and Long-Term Implications

The consequences of gadget-induced sleep deprivation are profound and multi-domain. Acutely, it impairs concentration, memory consolidation, and academic performance (Dewald-Kaufmann et al., 2013). Emotionally, it leads to increased irritability, stress, and emotional instability, which can create a vicious cycle of poor sleep and worsened mood (Lemola et al., 2015). The long-term developmental implications are severe. Persistent sleep disruption during adolescence can alter neural architecture, affecting prefrontal cortex maturation and executive function (Giedd, 2015). Longitudinal studies link technology-related sleep problems to a significantly higher risk of anxiety and depressive disorders in early adulthood (Lemola et al., 2015). Metabolically, sleep deprivation dysregulates appetite hormones, increasing the risk of obesity and establishing lifelong health vulnerabilities (Cappuccio et al., 2008). These wide-ranging impacts underscore sleep's foundational role in adolescent health.

Interventions and Implementation Challenges

Several interventions have demonstrated efficacy. Research indicates that reducing screen time one hour before bed or using blue-light-filtering glasses can increase sleep duration. Preventive efforts through school-based digital literacy programs and family-centered rules (e.g., digital curfews, charging stations outside bedrooms) are essential components (Owens et al., 2014). However, significant implementation barriers persist. Adolescent resistance driven by peer pressure and identity formation, the educational necessity of devices, inconsistent parental enforcement, and the rapid evolution of digital platforms all complicate intervention (Twenge, 2017). A multi-stakeholder approach is necessary, combining technical solutions (e.g., robust night modes), behavioral strategies, educational components, and public health campaigns that engage adolescents as partners in designing solutions for healthy digital habits.

Conclusion

In conclusion, the synthesis of evidence presented in this review unequivocally demonstrates that excessive and poorly timed gadget use constitutes a major disruptor of adolescent sleep. The negative impact is mediated through a powerful convergence of physiological pathways, primarily blue light exposure that suppresses melatonin and delays circadian rhythms, and potent psychosocial drivers, such as cognitive hyperarousal from interactive content and the anxiety fueled by Fear of Missing Out. This disruption manifests in reduced sleep duration, poorer sleep quality, and increased sleep onset latency, creating a cascade of detrimental effects. These consequences critically impair daytime functioning, undermining academic achievement, emotional stability, and cognitive performance, while also establishing long-term risks for mental health disorders, metabolic issues, and compromised neurological development. Mitigating this pervasive issue demands a systematic and multilayered intervention strategy that extends beyond individual responsibility.

Success hinges on the integrated efforts of adolescents themselves, families, educational institutions, technology designers, and public health authorities. Effective measures include the consistent enforcement of pre-sleep digital curfews, the adoption of built-in device features that minimize blue light and interruptions, and the implementation of comprehensive digital literacy and sleep hygiene education programs within school curricula. Ultimately, fostering an environment—both at home and in society—that values and protects sleep as a non-negotiable pillar of health is paramount. By equipping adolescents with the knowledge, tools, and supportive structures to manage their digital lives mindfully, we can safeguard their sleep, thereby nurturing their resilience, well-being, and capacity to thrive in an increasingly connected world.

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NOSTALGIA IN MUSICAL LYRICS WITHIN THE ORKESTRA JAWA SENANDUNG KIDUNG BOCAH

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Received: 22 October 2025; Accepted: 16 December 2025

Abstract

The long-held belief that nursery songs are exclusively for children is not entirely accurate. Nursery songs are created by adults from the perspective of a child. Essentially, these songs are a reflection of an adult's stories or imagination about a joyful and memorable childhood. This impression is evident in the lyrics and words found in the nursery songs. Understanding the gap between nursery songs from a child's perspective and that of an adult presents an opportunity for a new discourse on their transformation in the current digital era. This study investigates the transformation of nursery songs in the digital era and within the *Orkestra Jawa Senandung Kidung Bocah* (OJSKB). To achieve this, a mixed-method approach was used, comparing the traditional nursery folk songs (*lagu dolanan anak*) with their modern renditions by the OJSKB, and interpreting secondary data from existing literature. The analysis follows three main stages of restatement: (a) rephrasing the data to ensure an accurate understanding; (b) finding and describing the patterns within the data; and (c) interpreting the findings. The research findings are expected to demonstrate the transformation of nursery songs in terms of orchestral arrangement, the manner in which adults perform them, and the musical nostalgia they evoke. This study provides empirical evidence of how children's songs are being transformed in the present.

Keywords: children's songs, Javanese orchestra, musical lyrics, nostalgia

Introduction

Amidst the proliferation and widespread adoption of foreign and colloquial languages, it has been observed that a segment of Indonesian musicians remains devoted to expressing themselves through songs in Javanese and Indonesian, with a particular focus on children's songs. This phenomenon is by no means recent; it has persisted over time, aligning with the ever-changing dynamics of the Indonesian music industry.

As articulated by Merriam (1964), music fulfills several critical functions, including: serving as a physical response, a medium for communication, an outlet for emotional expression, a form of symbolic representation, a mechanism for reinforcing conformity to social norms, a contributor to cultural continuity and stability, an agent for societal integration, a source of aesthetic pleasure, and a means of entertainment. The contemporary transformation of traditional children's play songs (*lagu dolanan anak*), notably exemplified by the emergence of the



Javanese orchestra *Senandung Kidung Bocah*, constitutes a compelling phenomenon. This group is noteworthy for revitalizing these traditional songs within a fresher orchestral format, thus enhancing their appeal and acceptability among the younger generation. Furthermore, these children's play songs have been demonstrably linked to evoking musical nostalgia.

The purpose of this research is to address the shortcomings of previous studies, which have paid insufficient attention to children's songs that adapt and transform amidst the current prevalence of adult songs. The rise of adult songs being sung by children has an impact on children. Simultaneously, it is uncommon to find adults singing children's songs from an adult interpretation. The emergence of this new perspective from adults causes children's songs to undergo a transformation in both musical and non-musical aspects.

The Transformation of Traditional Children's Play Songs

Studies concerning the transformation of art can be broadly categorized into several tendencies. Firstly, there are transformation studies that focus on changes in the form of artistic presentation (Parmadie et al., 2018). Further research by Putra et al. (2023) illustrates how the conception of instruments, songs, and the scale system of the traditional *Krumpyung* music were modified to become more modern, such as through the use of electric guitars, bass, and drums. Meanwhile, the songs performed are contemporary, featuring a change in the nuance of the *dangdut* genre, which is blended with a diatonic scale system. The objective of this modification is not to alter the authenticity of the traditional *Krumpyung* music, but rather to serve as a persuasive step toward regeneration and community support for traditional music. Secondly, there are studies on the transformation of media in art (Diaz, 2016). This type of study primarily examines the transformation of art based on the tools or media used in the artwork, focusing on how art adapts to changes and the current trend of digitalization. The studies mentioned above demonstrate the complex academic discourse regarding the transformation of art.

Method

The research methodology employed is qualitative, focusing on traditional children's play songs (*lagu dolanan anak*) that have been arranged in an orchestral format. The musical and lyrical meanings are analyzed, and subsequently, coding is applied to ascertain the musical nostalgia present in the children's play songs.

Findings and Discussion

Children's Play Song Lyrics

Lyrical texts possess both a physical and an internal structure. The physical or linguistic structure can be divided into several elements, including: diction, imagery, concrete words, figurative language (rhetorical devices), versification, and textual layout. Conversely, the internal structure consists of four elements: theme (sense), the poet's feeling, tone, and message (intention). The utilization of songs as a medium is quite effective in conveying a message. The words within the song lyrics play a crucial role in message delivery. It is also asserted that when a person hears or sees words, a mental concept or image is formed. These concepts subsequently connect with the realities or objects existing outside of language, a

process known as association. The relationship between the concept and the objects it refers to is termed reference.

Furthermore, it is explained that word choice, or diction, is fundamentally the result of the deliberate effort to select specific words for use in sentences, paragraphs, and discourse. Based on this expert opinion, the author posits that diction is the outcome of selecting words through a person's mastery of vocabulary, which they deem appropriate for use in writing or speaking (Wijana, 2015). Below is an example of children's play song lyrics.

*Kidang talun mangan kacang talun
Mhil kedhemil mil kedhemil, si kidang mangan lembayung
Tikus pithi nduwe anak siji, cicit cuwit cicit cuwit
Maju perang wani mati
Gajah belang, seka tanah sebrang
Nuk renggunuk nuk renggunuk, gedhene meh padha gunung
(Kidang Talun)*

The description of the song *Kidang Talun* is a depiction of the *kidang*, a type of deer or small ruminant, eating heartily. The phrase "*mil kethemil mil kethemil*" suggests an association with enjoying food slowly and thoroughly, nibbling bit by bit. Similarly, the small mouse is described with the sound "*cicit cuwit cicit cuwit*." The following stanzas shift to a story about an elephant that comes from a land across the sea, outside of Java. Its massive body is likened to a mountain, and its slow walk is described using the phrase "*nuk renggunuk nuk renggunuk*."

*Menthok-menthok tak kandhani
Mung rupamu angisin-ngisini
Mbok yo aja ngetok, ana kandhang wae
Enak-enak ngorok ora nyambut gawe
Menthok menthok mung lakumu
Megal-megol gawe guyu
(Menthok)*

The description of the song *Menthok* (Muscovy Duck) is a portrayal of the animal whose slow walk, described as *megal-megol* (waddling or swinging its hips from side to side), causes observers to laugh. Its appearance is noted as unattractive and embarrassing, leading it to simply remain inside the pen, sleeping and engaging in no activity.

From the children's play songs *Kidang Talun* and *Menthok*, a shared theme emerges: the theme of animals that are easily encountered or already familiar. Consequently, the author projects their feelings into the song lyrics with an appealing tone and rhyme, and incorporates a moral lesson to observe and learn from the behavior of these animals.

Diction, imagery, concrete words, figurative language (rhetorical devices), and versification are captivating elements within these children's play songs. Concurrently, there are four elements of the internal structure: theme (sense), the poet's feeling, tone, and message (intention). Another song example is as the following.

*Kodok ngorek kodok ngorek, ngorek pinggir kali
Theot teblung theot teblung, theot theot teblung
Bocah bodo bocah bodo njaluk dijamoni
Jamu apa, jamu apa? Jamu temu temu lawak
Bocah pinter bocah pinter sesuk dadi dokter
Numpak motor numpak motor numpak motor mabur
(Kodok Ngorek)*

A number of songs translated from Javanese children's play songs into Indonesian are also sung, alongside the Javanese originals. One such translation is the song *Kodok Ngorek* (Croaking Frog) which becomes:

*Kodok ngorek kodok ngorek, bernyanyi di pinggir sungai
Theot teblung, theot teblung begitu bunyinya.
Anak pintar anak pintar belajar yang jujur
Apapun cita-citamu pasti terwujud*

The outpouring of words, which are strung together to convey an idea, must be clear, concise, and precise, so as not to cause misinterpretation. Clear means that the word choice and structure are correct; concise means not verbose; and precise means not ambiguous. A good understanding of writing rules is expected to achieve this. It is further stated that when creating lyrics, a poet or songwriter must be truly skilled in processing words. Through a song, a person expresses feelings, hopes, aspirations, and ideals that reflect the worldview and spirit of their era.

From this perspective, the beauty of children's songs becomes more apparent when they are sung with the right arrangement (Abdullah et al., 2023). Previously, children's songs were often sung in a simple form, typically with only one voice and basic musical accompaniment such as piano or guitar (Lytra, 2011). While this simple arrangement was sufficient to introduce the melody and lyrics to children, children's songs began to be arranged more complexly as time evolved (Borukh, 2019). Modern arrangements not only add harmony and more dynamic rhythms but also integrate more varied contemporary musical elements (Gammon, 2011). The addition of backing vocals, group vocal arrangements, and the use of digital technology make children's songs more engaging and align with the tastes of today's children (Khoiro, et al., 2023). This change does not diminish the essence of the children's song itself; rather, it enriches the experience of listening to and singing the song (Yang & Lee, 2017), causing children's songs to transform in both musical and non-musical aspects.

1. Javanese Orchestra Kumandang Kidung Bocah

According to Guntur Nur Puspito, the Javanese Orchestra *Kumandang Kidung Bocah* was formed on July 23, 2024. This date also marked their first performance, held in commemoration of National Children's Day. This orchestra is a collaboration with the relevant agency, the UPT Taman Budaya Yogyakarta, and is fully supported by the Department of Culture (*Kundha Kabudayan*) of the Special Region of Yogyakarta.

Guntur's reason for reviving traditional children's play songs (*lagu dolanan bocah*) stems from his concern over the proliferation of mass-marketed adult

content heavily consumed by minors. Guntur hopes that the performance of the *Kidung Bocah* songs will reintroduce noble cultural works (*karya-karya adiluhung*) and serve as a medium for nostalgia for the generations of the 80s and 90s.

Furthermore, the Head of the Special Region of Yogyakarta Department of Culture (Kundha Kabudayan), Dian Lakmi Pratiwi, emphasized that the choice of children's song repertoire presented in this event is not merely for entertainment, but also an effort to provide an understanding of local cultural values closely associated with Javanese local wisdom. Thus, the children's play songs are expected to serve as an educational tool that enriches knowledge and imparts positive values to the younger generation.

She also stated that the orchestral music form can act as a bridge and inspire children to continue to love and understand the traditional values they have inherited. The Javanese Orchestra Kumandang Kidung Bocah offers a new perspective, providing not only a captivating artistic experience but also revitalizing the beauty of children's songs that are often overlooked.



Figure 1. The *Kendang* Instrument in the Orchestra

The traditional instrument played in the orchestra is the gendang or kendang (Javanese drum), which collaborates with the percussion section and the orchestra as a whole. In certain sections, a kendang solo is featured to provide a strong, traditional Javanese regional nuance.

2. *Musical Transformation of Traditional Children's Play Songs*

The musical transformation is evident in the melodic aspect, which is enriched and features a greater variety of melodies. The use of diverse and complex chords and harmonies also supports the transformation of the play songs into an orchestral format. The instrumentation is richer because various orchestral instruments are aligned and complement the traditional instruments in accompanying the play songs. This results in a broad musical dynamic, composed by the arranger and orchestra conductor, Guntur Nur Puspito. The musical texture is a more complex polyphonic or homophonic structure.

Table 1. Musical Aspects of Traditional Children's Play Songs

Aspect	Traditional Children's Play Song	Children's Song with Orchestra
Melody	Simple, easy to remember	Enriched, has variations
Harmony	Simple or non-existent	Complex, uses various chords
Accompaniment	Simple (hand-clapping, simple instruments) or a <i>cappella</i>	Rich, involves various orchestral instruments
Dynamics	Limited, dependent on the children's singing	Broader, regulated by the conductor and arrangement
Musical Texture	Monophonic or simple homophonic	Polyphonic or more complex homophonic

3. *Transformation of Sociocultural Aspects*

The presentation in the orchestral format provides a new atmosphere, and this novelty is evident in the context of usage, participation, cultural preservation, and emotional impact. In the context of music performance, the concert serves as a means of education and recording. Participation is more passive for the audience, focusing on the appreciation of the performance as it constitutes a new experience. This transformation is an innovative way to introduce and preserve children's play songs as an aspect of cultural heritage preservation. The audience response demonstrates admiration, appreciation for the beauty of the music, and a deeper emotional involvement.

Table 2. Socio-Cultural Aspects of Traditional Children's Play Songs

Aspect	Traditional Children's Play Song	Children's Song with Orchestra
Context of Use	Children's games, daily social interaction	Music performances, educational concerts, recordings
Participation	Active, all children can sing and move	More passive for the audience, focuses on appreciating the performance
Cultural Preservation	Direct way of passing on oral traditions and cultural values	Innovative way to introduce and preserve play songs
Emotional Impact	Sense of togetherness, joy in playing	Awe, musical beauty, deeper emotions



Figure 2. *Buto Cilik* dance serves as a complement to the song *Buto Galak*, performed with agility to better illustrate the lyrics of the children's play song.

*Buto-buto galak, solahmu lunjak-lunjak
Sarwi sigrak-sigrak, nyandhak kanca nuli tanjak
Bali ngadheg maneh, rupamu ting celoneh
Iki buron apa tak sengguh buron kang aneh
Lha wong kowe..we..we..sing marai ihi-ih
Aku wedi ayo kanca padha bali
Galo kae galo kae, mripate plerak-plerok
Kulite ambengerok
Hi hi hi aku wedi
Ayo kanca padha bali*



Figure 3. The blending of the play song and the dance depicts (or illustrates) children's play.

4. Repertoire

Traditional children's play songs (*Lagu Dolanan anak*) are usually written in numerical notation (cipher notation), and singers are given the freedom to

determine their own vocal pitch, with only the numerical notation listed, as shown in the example below:

Figure 4 displays the notation of traditional children's play songs, showing four lines of musical notation with corresponding lyrics. The notation uses numbers (1-7) and rests (0) to represent pitch, with chords (Em, F) indicated above the notes.

Line 1: (Em) 4 5 | 7 . 1̇ 7 | 5 3 4 5 | 0 7 5 4 | 3 . 3̇ . 3̇ |
Ja ra nan ja ra nan ja ra ne ja ran te ji sing num

Line 2: | 3̇ 1̇ 7 1̇ | 3̇ . 3̇ . 3̇ | 3̇ 1̇ 5 1̇ | 7 . 1̇ 1̇ |
pak do ro be hi sing ngi ring pa ra men tri jrek jrek

Line 3: | 7 . 1̇ 1̇ | 7 3 4 5 | 0 7 5 4 | 3̇ 3̇ 4 5 |
nong jrek jrek gong jrek e jrek tu rut lu rung gedebuk krin

Line 4: | 3̇ 3̇ 4 5 | 3̇ 3̇ . 3̇ | 0 3̇ 4 5 4 | 3̇ . |
cing gedebuk krincing thak thak gedebuk je der

Figure 4. Notation of Traditional Children's Play Songs

Conversely, in the orchestral format, the notation for all instruments is precisely and definitively specified according to what is written.

Figure 5 displays examples of children's song repertoire in the orchestra, showing a page of musical notation for multiple instruments and a vocal line. The notation includes staves for various instruments (flutes, oboes, clarinets, bassoons, strings, and woodwinds) and a vocal line with lyrics.

The lyrics are: In - do - ne - sia, In - do - ne - sia, A - ku bangga me - ri - a - nak In - do - ne - sia.

Figure 5. Examples of Children's Song Repertoire in the Orchestra

5. Musical Nostalgia

Nostalgia, as a new concept, emerged after Johannes Hofer combined nostos (home) and algos (torment) to describe the feeling of wanting to return home among soldiers on the battlefield. This feeling stirred memories of a safe, comfortable, and peaceful home, but their inability to return caused torment. Nostalgia is not merely a private and personal matter; it also involves geography, leading to the formation of communities to gather and recollect past memories. Alvin Toffler referred to nostalgia as the third wave, following the agricultural and industrial revolutions. Change is addressed by either adapting and accepting it or by returning to the past. Furthermore, nostalgia is found not only to trap memory but also to motivate our

actions in the present. Nostalgia can concurrently thrive as hope, being both retrospective and prospective.

The event, which was held as part of the music arts development program by Taman Budaya Yogyakarta, featured a repertoire of children's songs that have become part of the nostalgia for many generations. Ranging from "*Tak Lela Lela Ledhung*", "*Lir-Ilir*", to "*Padhang Bulan*", each song possesses its own charm capable of evoking sweet childhood memories.

The experience of listening to these traditional children's play songs (*lagu dolanan anak*) when one is already an adult or a parent brings back memories of the past. Some of these memories or instances of nostalgia include:

a. Memories of parents

Children's play songs bring back memories of the mother, father, or grandparents who chanted the songs during childhood. As expressed in the following impressions:

"Kidang Talun reminds me of my late Father. When I was little, I was often entertained by the shadow of a hand on the wall forming a kidang (deer) head while he sang this song" (A)

"It reminds me of when I was small, being sung to right before bedtime 60 years ago by my late Father and Mother" (B)

Childhood memories under the care of parents who told stories and sang the *Kidang* song become an unforgettable experience. The sense of closeness (A) with a parent, particularly the Father, is clearly evident upon listening to the *Kidang* song as it is revived in *Kumandang Kidung Bocah*. The experience and nostalgia of childhood resurface, even after more than 60 years for (B). The bedtime memories still strongly associated with the *Kidang* song bring forth a deep longing for parents, even when the listener has become a parent themselves.

b. Memories of the hometown

Traditional children's play songs also serve as a reminder of one's hometown. The longing of the diaspora living abroad to return to their hometown is expressed in the following statement:

"One of the things that makes it impossible to let go and makes me want to immediately return home to Indonesia is its kidungs (songs) / dendangs (chants). Greetings from an overseas migrant." (C)

"Very nice listening to some of the songs my grandmother taughted us...grandmother mbah Sitoek keturunan Jawa living and now I live in Rep. Suriname...South America" (D)

Kumandang Kidung Bocah becomes a remedy for the longing for one's homeland in Indonesia, but also a reminder of the ancestors originating from the island of Java.

c. *Experience of playing events*

Children's play songs indicate that these songs accompanied the childhood experience of playing, along with the atmosphere surrounding it, as shown in the following quotes:

"My dance when I was little was just like this; it reminds me of everything. It felt so good when it was a bright evening, with the moonlight, playing with friends. Peace be upon us." (E)

"I'm touched, it reminds me of when I was little, playing in the yard under the bright full moonlight." (F)

d. *Experience with the Javanese Orchestra*

"Amazingly cool, the orchestra is unique because it blends various instruments, both traditional and modern. The songs used are also Javanese children's play songs that make us nostalgic for childhood. This is also a way to preserve the nation's culture."

"I almost couldn't hold back the tears, listening to songs from my childhood, supported by a beautiful arrangement that pays attention to the theme and lyrics of each song. Is it because I miss these songs so much... sluku sluku batok, buto galak, jaranan, kodok ngorek, lir ilir, kembang jagung etc... rare songs that are almost lost to time. Thank you and congratulations on the success of the Javanese Orchestra team. May good fortune always accompany every step of the team members... greetings from Blitar, the Land of Bung Karno. Rahayu rahayu (peace and prosperity)." (G)

Conclusion

The Javanese Orchestra 'Kumandang Kidung Bocah' is not merely a music performance, but also an artistic offering that evokes nostalgia and takes the audience on a journey through their childhood. With such great enthusiasm from the public, the Javanese Orchestra and this event serve as proof of the importance of musical art in enriching and weaving cultural diversity in Yogyakarta. The musical nostalgia transformation in the Javanese Orchestra *Senandung Kidung Bocah* (Note: The text appears to mix the names, using *Senandung Kidung Bocah* here instead of *Kumandang Kidung Bocah*) is evident in aspects such as melody, harmony, accompaniment, dynamics, and musical texture. Furthermore, it also carries the aspects of cultural preservation, introducing Javanese cultural heritage to the younger generation, and in the realm of music education, expanding musical insight into one's own traditions. Additionally, it serves as an artistic appreciation effort to foster love for Javanese music and its collaborations. This collaboration also enhances intercultural understanding by opening a window for audiences from other regions to recognize children's play songs in Java, which likely also exist in other regions with different variations and languages but contain the same message and context.

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INNOVATING CLIMATE AND RENEWABLE ENERGY EDUCATION THROUGH DEEP LEARNING AND THE ENGINEERING DESIGN PROCESS

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Received: 31 October 2025; Accepted: 16 December 2025

Abstract

The rapid advancement of digital technology has transformed educational practices, demanding innovative approaches that foster deep learning and connect knowledge with real-world contexts. This study aims to develop a deep learning pedagogical model based on the Engineering Design Process (EDP) and a triple learning approach (meaningful, mindful, and joyful learning) within renewable energy projects in the digital era. An implementation approach was applied through contextual projects in which students designed and constructed renewable energy systems, engaging in continuous research, critical reflection, and problem-solving. The projects were carried out following the stages of the EDP, namely problem identification, ideation, planning, implementation, testing, and evaluation. The results indicate that the integration of EDP with a deep learning approach enhances active engagement, interdisciplinary conceptual understanding, and reflective awareness of energy sustainability issues. Students demonstrated critical, creative, and collaborative thinking skills through meaningful and enjoyable learning experiences. This model not only fosters ecological awareness but also develops scientific competencies relevant to the demands of 21st-century education. Therefore, the integration of EDP and the triple learning approach represents an educational innovation that supports transformative learning and aligns with the Sustainable Development Goals (SDGs).

Keywords: deep learning, educational innovation, Engineering Design Process, renewable energy education

Introduction

The changing era, marked by advancements in technology and science, necessitates adjustments within the educational system. Education is expected to produce a generation that is not only academically competent but also aware and skilled in addressing global challenges. One of the major issues that must be addressed through education is the climate crisis. Climate change has become one of the defining global challenges of the 21st century, characterized by rising global temperatures, extreme weather events, and environmental crises that threaten the sustainability of human life. One of the primary causes is humanity's dependence on fossil fuels, such as oil, coal, and natural gas, which produce significant greenhouse gas emissions.

In the *Laudato Si'* encyclical, Pope Francis (2016) emphasizes that the environmental crisis is closely linked to a moral and value crisis concerning



humanity's responsibility toward creation. Excessive exploitation of nature and a consumptive lifestyle reflect a failure to understand the moral duty of stewardship over creation. Ultimately, this moral crisis leads to indifference toward the ethical responsibility of preserving creation, including a lack of concern for future generations who will bear the consequences of environmental degradation. Therefore, healing the relationship between humanity and nature requires a transformation of mindset and awareness that caring for the Earth also means upholding human dignity and safeguarding the future of generations to come.

In line with the demands of 21st-century education, students are challenged to develop critical, collaborative, creative, and communicative skills (4C) (World Economic Forum, 2016). These competencies are highly relevant when students are confronted with global issues such as the energy crisis and climate change. The topic of renewable energy can serve as a contextual and meaningful learning medium that simultaneously fosters ecological awareness. Thus, integrating renewable energy issues into educational practices presents a strategic opportunity to cultivate a generation that is adaptive and responsive to global challenges.

However, in reality, the current education system still faces a number of challenges that hinder the achievement of these goals. One of the main factors contributing to students' low awareness of climate change and renewable energy utilization is a curriculum that has not yet fully adapted to the needs of the surrounding environment. A curriculum pattern that places excessive emphasis on theoretical content causes learning to lose its relevance to real-life contexts. As a result, students struggle to develop critical thinking and creativity skills and are often unaccustomed to addressing complex problems systematically.

Furthermore, teaching methods that remain focused on rote memorization exacerbate this issue. Most students are accustomed to memorizing rather than understanding, causing knowledge to become goal-oriented and temporary, limited to achieving report card grades or meeting graduation requirements. Such an approach emphasizes curriculum completion rather than the development of students' learning abilities (Nuha et al., 2024). Consequently, much of the knowledge acquired during basic education tends to be forgotten. This has also been observed by the author during informal mentoring sessions in student scientific competitions, where participants often struggled to grasp the fundamental scientific concepts underlying their research projects.

To address the challenges of 21st-century education and the digital era, a learning approach is needed that not only focuses on product outcomes but also fosters deep and reflective thinking processes. The Engineering Design Process (EDP) integrated with deep learning principles offers an innovative strategy to achieve this objective. Through a systematic sequence of stages, students are trained to connect scientific and technological concepts with real-life contexts (*meaningful learning*), to develop awareness of their cognitive processes and emerging values (*mindful learning*), and to experience positive emotional engagement during exploration (*joyful learning*).

Therefore, this article aims to develop a deep learning pedagogical model based on the EDP and the triple learning approach (meaningful, mindful, and joyful) within renewable energy projects in the digital era. It is expected that this work will make a substantial contribution to the development of educational

practices aligned with the values of *Laudato Si'* while simultaneously supporting the achievement of the Sustainable Development Goals (SDGs).

Deep Learning

Deep learning in the context of education refers to a learning process that emphasizes deep, critical, and meaningful conceptual understanding. This approach focuses on constructing knowledge through active student engagement, enabling students to move beyond rote memorization (*surface learning*) and to connect learned concepts with real-life contexts (Prihantini et al., 2025). Deep learning encourages students to develop critical and creative thinking skills, as well as problem-solving abilities relevant to the challenges of the 21st century. This approach is not entirely new; rather, it represents a pedagogical orientation aimed at enhancing learning effectiveness by emphasizing student activity, reflection, and collaboration (Khotimah & Abdan, 2025). In the context of Indonesian education, the implementation of deep learning is essential for cultivating critical and adaptive mindsets among both students and teachers, equipping them to navigate the complexities of the digital era and globalization (Diputera et al., 2024).

Furthermore, the deep learning approach integrates three core elements: meaningful learning, mindful learning, and joyful learning (Feriyanto & Anjariyah, 2024). First, *meaningful learning* connects new knowledge with prior understanding, allowing students to comprehend concepts contextually. Second, *mindful learning* emphasizes full awareness, focus, and reflection throughout the learning process. Third, *joyful learning* fosters an enjoyable and motivating learning atmosphere, wherein happiness serves as a crucial factor in enhancing engagement and learning outcomes.

Engineering Design Process (EDP)

The Engineering Design Process (EDP) is a systematic way of thinking used to teach and apply concepts and skills in an integrated manner. The EDP approach is increasingly used in Science, Technology, Engineering, Arts, and Mathematics (STEAM) education as a strategy to develop students' creative, critical, and collaborative thinking skills. EDP is seen as a new trend in science education reform because it provides contextual learning experiences through systematic engineering stages, from identifying problems, designing solutions, testing, and evaluating, to communicating results (Jolly, 2016; Winarno et al., 2020).

The main stages of EDP include identifying the problem along with criteria and constraints (*identify*), exploring and generating ideas (*imagine*), developing plans and selecting group designs (*plan*), building prototypes and testing results (*create*), and improving designs based on evaluation outcomes (*improve*). This process is iterative, meaning that each step can be repeated to allow for continuous improvement. In its implementation, students are also encouraged to engage in reflection and communication, both about the process and the results, fostering critical thinking, resilience, and more comprehensive STEM skills (Texas Education Agency, 2022).

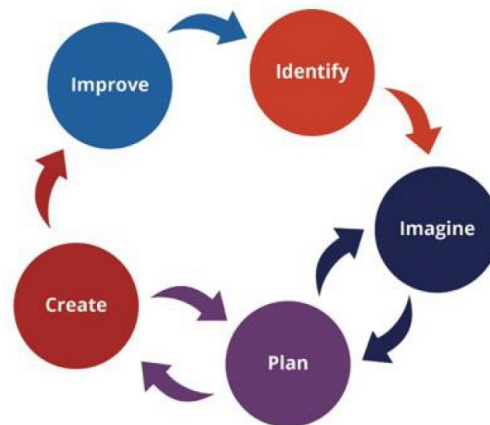


Figure 1. Main stages of the Engineering Design Process (Texas Education Agency, 2022)

By applying EDP, research by Sudrajat et al. (2023) showed a significant improvement in students' creative thinking skills and product creativity in the topic of alternative energy. This finding demonstrates that EDP is not only effective in enhancing the understanding of scientific concepts but also in developing 21st-century skills that are essential for addressing global challenges such as the energy crisis and climate change.

Method

This study was conducted within the Sanggar Ursula Community, a non-formal, technology-based learning space that serves as a bridge between the application of science in real-world contexts and academic learning. The research subjects included junior and high school students as well as university students participating in the *Electronics Science Program*, either through extracurricular activities or specialized mentoring sessions for scientific project competitions. Participants who joined the Sanggar Ursula Community met several criteria: they demonstrated an interest in science and technology projects and expressed willingness to engage in the full sequence of EDP-based activities. The focus of the study was directed toward observing the learning process, strengthening practical skills, and developing students' abilities to integrate scientific and technological concepts through applied project-based activities.

This research employed a qualitative approach with an implementation study design. This approach was chosen to explore in depth how a project-based learning process focusing on the design and development of renewable energy systems can enhance students' problem-solving skills. The data sources consisted of direct observations of student activities within the Sanggar Ursula Community, where participants engaged in Engineering Design Process (EDP)-based learning.

The study adopted the EDP framework as the primary approach to integrating deep learning into project-based renewable energy system learning. EDP was selected for its systematic stages that encourage students to think critically and creatively through authentic learning experiences. Each stage of the EDP was integrated with the three elements of deep learning, namely meaningful, mindful, and joyful learning, to promote a holistic and reflective learning process.

In the problem identification stage, students were guided to foster *meaningful learning* by generating ideas derived from real-world environmental issues and connecting them to national and global concerns. This process helped students recognize the meaning and relevance of their learning to everyday life. Subsequently, the preliminary research stage was designed to cultivate *mindful learning*, in which students explored the scientific principles underlying their project ideas, conducted observations, and analysed relevant literature to ensure that their project rationales were supported by a strong scientific foundation. In the project planning stage, students developed activity designs, identified necessary resources, and determined timelines and cost estimations. The project implementation stage integrated *joyful learning* through hands-on activities such as executing project plans, collecting data, creating prototypes, and conducting testing. The final evaluation stage involved reflection, discussion, and feedback sessions aimed at encouraging continuous improvement. The EDP framework, when integrated with the three elements of *deep learning*, not only reinforces students' mastery of scientific concepts but also enhances their critical, creative, collaborative, and communicative (4C) skills, competencies that are essential for 21st-century learning.

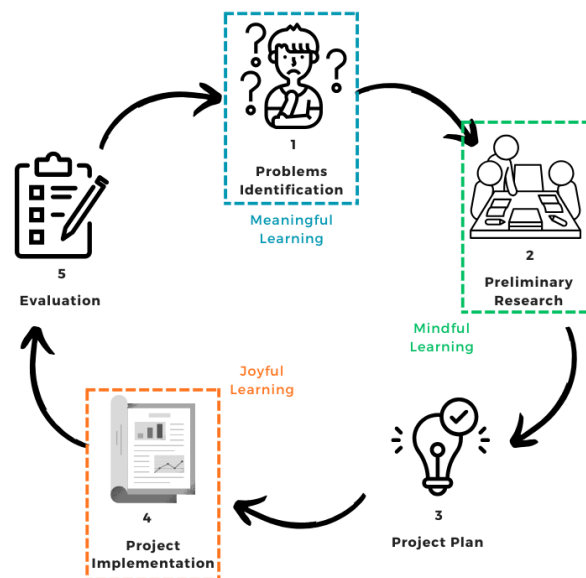


Figure 2. Flow diagram of the Engineering Design Process (Author's illustration)

Data were collected through observation, documentation of students' project activities, and informal interviews. Because the learning environment was non-formal, observations were conducted continuously as students progressed through the stages of the EDP. The researcher observed students' interactions, prototype development, and their reflections and responses to the learning experiences.

Data analysis was conducted using a qualitative-descriptive approach through three stages. The first stage was data reduction, which involved sorting and selecting data obtained from observations, documentation, and students' reflections according to the focus of the study. The second stage was data presentation, in which information was organized into categories such as critical thinking, collaboration, creativity, and problem-solving skills. The third stage was conclusion

drawing, which entailed interpreting the findings based on the EDP and deep learning frameworks to assess students' developmental progress.

Findings and Discussion

An example of implementing the EDP in the context of climate change and renewable energy is a project focused on regulating the conversion of multiple renewable energy sources, such as solar, hydro, and wind energy, into electrical energy. The idea for this project originated from observations of society's dependence on fossil fuels and their detrimental environmental impacts. On the other hand, the intermittent nature of renewable energy poses unique challenges in maintaining energy supply stability. Students were guided to recognize the importance of clean and sustainable energy and to understand that carbon emission reduction can be achieved through innovations in renewable energy technology.

During the preliminary research stage, students were trained to conduct simple observations of natural energy potentials in their local environment. In addition, they explored literature on the basic principles of energy conversion, including the laws of energy conservation, Ohm's Law, and Kirchhoff's Law, as foundational knowledge for electrical system calculations. This stage not only aimed to deepen their theoretical understanding but also to build a rational foundation for their project ideas based on real-world conditions.

Subsequently, students were introduced to designing a multi-source energy conversion system in the form of a block diagram. The energy generated from various sources was designed to flow into a control system equipped with autonomous correction mechanisms. The system's output was then directed toward an energy storage component.

In the final evaluation stage, the focus was placed on the engineering process of the energy conversion system and the quantitative measurement of the renewable energy fluctuations produced. The primary goal of this learning activity was to introduce students to the principles of renewable energy conversion into electricity while fostering awareness of the interconnection between scientific knowledge and God's creation, nature itself.



Figure 3. Project-based learning activities incorporating the Engineering Design Process (Author's documentation)

As another example, students applied the stages of the EDP through the design of a *Green Bicycle*, a mode of transportation capable of converting solar energy through solar panels and mechanical energy from pedalling into electrical energy. The project began with students' observations of carbon emissions produced by motor vehicles and their impact on climate change. From these

observations and classroom discussions, students realized the need for eco-friendly transportation innovations that could reduce dependence on fossil fuels. This awareness served as the initial foundation for cultivating ecological responsibility and motivation to develop tangible solutions.

During the preliminary research stage, students sought references on the working principles of solar panels, generators, and electrical energy storage systems. They applied these principles to strengthen the design foundation of the project according to real-world needs in their surrounding environment. Subsequently, students were trained to design a system that utilizes solar panels to capture sunlight and generators to convert kinetic energy into electrical energy. In this design process, physics concepts such as kinetic energy, solar energy, and energy efficiency served as the basis for technical decision-making. Next, students were guided to assemble a prototype of the “green bicycle” using simple materials, including used bicycles, mini solar panels, small dynamos, and batteries.

In the final evaluation stage, reflection became the main focus. Students were encouraged to relate the project to global issues of carbon emission reduction and the role of individuals in shaping sustainable technology. The *Green Bicycle* project not only emphasized an understanding of energy concepts but also fostered students’ ecological awareness in seeking environmentally friendly transportation solutions. Beyond increasing awareness of climate change, this learning experience nurtured students’ innovative attitudes, technical skills, and critical thinking in exploring sustainable alternative energy solutions.



Figure 4. *Green Bicycle* as part of the Engineering Design Process (Author’s documentation)

Both projects demonstrate that the implementation of the EDP, when integrated with deep learning, plays a crucial role in fostering meaningful learning experiences. Through this approach, students not only solve technical problems but also connect learning with social and environmental contexts. Each stage of the EDP serves as a reflective space where students learn to link concepts, conduct scientific exploration, and reassess their work outcomes. This process reflects the essence of deep learning, which emphasizes meaningful understanding and reflective awareness.

The integration of meaningful learning is evident when students recognize the relevance between energy concepts and real-life applications. They do not merely comprehend physical theories; rather, they connect scientific concepts with social contexts and ecological implications. In the multisource energy project, students learned that managing renewable energy sources can reduce dependence on fossil

fuels and promote environmental sustainability. Meanwhile, in the *Green Bicycle* project, they discovered how simple technologies can contribute to carbon emission reduction. The connection between scientific concepts and social contexts fosters ecological awareness, making the learning process more meaningful and contextual.

The element of mindful learning emphasizes reflective awareness toward thinking and acting during scientific inquiry. In the multisource energy project, students not only designed an automatic system to regulate energy conversion but also consciously observed energy supply imbalances, questioned their causes, and sought solutions. In the *Green Bicycle* project, as one student expressed, “*Tujuannya membuat energi bersih, karena energi kotor merusak dunia. Nggak mau kan nanti pas anak-anak dan cucu kalian harus pakai masker setiap mau keluar rumah,*” (“The goal is to create clean energy because dirty energy harms the world. You wouldn’t want your children and grandchildren to have to wear masks every time they go outside, would you?”). This shows their ability to connect technical decisions with ethical and environmental implications. This reflective process strengthens students’ ability to recognize the interrelationship between human actions, technology, and environmental sustainability. Hence, mindful learning cultivates a scientific mindset that is conscious of ecological consequences and the ethics of technology, making science learning not only intellectually rigorous but also morally grounded.

Meanwhile, the application of joyful learning creates a more engaging and creative learning atmosphere. Students expressed excitement when the *Green Bicycle* successfully powered a lamp, with several noting that it was their first time seeing their own energy production in action. This experience shows that project-based learning serves not only as a cognitive platform but also as an emotional and motivational one. The sense of joy and active engagement encouraged students to continuously explore new ideas and develop sustainable innovations.

Overall, the integration of meaningful, mindful, and joyful learning establishes a comprehensive, deep learning process, in which students not only develop a reasoned understanding of interdisciplinary concepts but also demonstrate reflective awareness of ecological issues and creative innovation in designing sustainable energy solutions. Theoretically, the findings indicate that integrating the three elements of deep learning with the Engineering Design Process (EDP) reinforces the characteristics of deep learning pedagogy within the context of digital era education. This learning model not only facilitates mastery of renewable energy concepts but also cultivates reflective, creative, and ecologically conscious ways of thinking. Thus, this approach can serve as a prototype for sustainable digital pedagogy that is relevant to the STEAM domain, particularly in addressing issues related to energy and environmental sustainability.

Observations and reflections of the learning process revealed that 21st-century skills, such as collaboration, scientific communication, and critical thinking, were effectively developed among students. They were able to engage in scientific discussions, present their design outcomes, and explain the operational principles of their prototypes to peers and instructors. In terms of awareness, project-based learning nurtured ecological empathy and a sense of environmental responsibility. Students began to perceive climate change not merely as a global problem but as a challenge that can be addressed through innovation and concrete

local actions. However, some students had not yet developed process awareness, as EDP and deep learning, based approaches require habituation to reflective thinking rather than focusing solely on final results.

Based on interviews and observations, students reported that project-based learning was far more effective than conventional, theory dominant methods. One student expressed,

“Menurut saya pembelajaran dengan metode project-based learning ini jauh lebih efektif dibandingkan belajar teori aja. Perlu diadakan di sekolah-sekolah, karena pada kenyataannya pengetahuan bukan sekedar ilmu, tetapi digunakan di dunia nyata. Tantangannya adalah bagaimana cara menggunakan ilmu itu,” (“In my opinion, project-based learning is far more effective than just learning theory. It should be implemented in schools because knowledge is not merely information; it is meant to be used in the real world. The challenge is how to apply that knowledge.”).

They perceived a direct connection between learning and real-world contexts, which made it easier to comprehend grand theoretical concepts. This finding aligns with the perspectives of Piaget and Dewey, who emphasized that students construct understanding through engagement with “real-life” experiences (Lu S.-Y. et al., 2021).

Despite these positive outcomes, implementing project-based learning through EDP and deep learning approaches also presents challenges. Some students required additional time to adapt, as such methods are rarely practiced in formal schools. Furthermore, internal motivation and social environmental support significantly influence project success. Therefore, to ensure sustainability, it is essential to provide teacher training, adequate learning facilities, and institutional policies that allow space for innovative pedagogical approaches.

Conclusion

Project-based learning through the Engineering Design Process (EDP) has been proven to foster a deep learning process that is meaningful, reflective, and joyful. Students not only comprehend the concepts of energy and their real-world applications but also internalize the values of sustainability and ecological responsibility as an integral part of their scientific awareness. The integration of meaningful, mindful, and joyful learning within each stage of EDP strengthens the learning process by emphasizing the interconnection between scientific knowledge, reflection on real-world problems, and innovation development. Therefore, this approach has the potential to serve as an innovative pedagogical model in the digital era, promoting STEAM learning that emphasizes environmental sustainability and the cultivation of critical and creative thinking skills.

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EXPLORING MATHEMATICAL LITERACY FOR PRESERVICE TEACHERS: IDENTIFYING CONTEXTS, CONTENTS, AND ACTIVITIES

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Received: 27 November 2025; Accepted: 17 December 2025

Abstract

Mathematics preservice teachers need to be well-prepared to teach students, particularly in fostering mathematical literacy, as the Indonesian government currently emphasizes literacy in both reading and mathematics. This study aims to describe preservice teachers' ability to identify mathematical literacy questions in terms of: 1) the context and content of the questions, and 2) the activities that support mathematical literacy. This study employed a quantitative descriptive research design using a survey method. Data were collected through a questionnaire administered to 176 mathematics preservice teachers from two universities in Yogyakarta. The data were analyzed using descriptive statistical techniques, including frequency and percentage distributions, to describe preservice teachers' responses. The findings reveal that 1) preservice teachers were able to identify scientific and personal contexts, but had difficulties in recognizing social and scientific contexts. They successfully identified contents related to space and shape, data and uncertainty, and quantity, but faced challenges with change and relationships. Furthermore, 2) preservice teachers demonstrated the ability to distinguish activities that support mathematical literacy. These findings provide insights for designing appropriate activities to strengthen preservice teachers' ability to identify mathematical literacy questions or design the questions themselves.

Keywords: mathematical literacy, mathematical task, mathematics teacher, numeracy, preservice teacher

Introduction

Mathematics education today emphasizes not only procedural knowledge but also mathematical literacy. In the 21st century, real-world problems are increasingly complex, requiring individuals to understand the role of mathematics in everyday life. This understanding enables individuals to critically evaluate and apply mathematics in ways that support constructive, caring, and thoughtful participation in society. The ability to reason and solve problems mathematically in real-world contexts is referred to as mathematical literacy (Rizki & Priatna, 2019).

Modern society requires more than just content knowledge; it also demands a broad set of skills, including critical thinking, problem-solving, creativity, innovation, communication, collaboration, flexibility, adaptability, initiative, self-direction, social and cross-cultural skills, productivity, accountability, leadership,



responsibility, and information literacy (Partnership for 21st Century Skills, 2009; Stacey, 2011; Wijaya, 2016). Mathematical literacy is a key component in developing these 21st-century skills (World Economic Forum, 2016).

Mathematical literacy refers to an individual's capacity to reason mathematically and to formulate, apply, and interpret mathematical concepts and procedures when solving problems in various real-world contexts (OECD, 2019; Bynner & Parsons, 2006; Baba, 2024). It involves using facts, tools, and strategies to describe, explain, or predict phenomena in personal, societal, or occupational contexts. Developing mathematical literacy equips students to become critical thinkers and informed decision-makers, essential qualities in contemporary society (Serin, 2023; Rio & Protacio, 2025).

Preservice teachers (PST) play a crucial role in shaping how mathematical literacy is taught in future classrooms. Their initial training must go beyond content knowledge, helping them understand how to connect abstract mathematical concepts to real-life situations. They must also develop a robust understanding of disciplinary literacy to design lessons that foster students' critical thinking and problem-solving skills (Colwell & Enderson, 2016). When preservice teachers master effective teaching methods and understand the broader applications of mathematics, they are better prepared to guide students. Ultimately, the quality of their preparation and their views on mathematical literacy determine whether students perceive mathematics as merely a set of rules or as a dynamic tool for understanding the world.

However, many preservice teachers still perceive mathematics as abstract and procedural rather than meaningful and applicable. Research indicates that a significant number of preservice teachers continue to see mathematics primarily as a collection of static rules and procedures instead of a dynamic, meaningful tool for solving real-world problems (Hatisaru et al., 2025; Fuentes et al., 2014). This limited perspective often constrains their ability to design learning experiences that connect mathematical ideas to students' real-life experiences. As a result, they may struggle to support the development of students' mathematical literacy, which requires integrating conceptual understanding with authentic problem-solving situations.

This study adopts the PISA framework (OECD, 2023; Golla & Reyes, 2022), which conceptualizes mathematical literacy along three dimensions: content (mathematical concepts and skills), context (real-world situations in which mathematics is applied), and activity or process (cognitive actions such as formulating, applying, and interpreting mathematics). In the PISA 2022 framework, mathematical reasoning and problem-solving are assessed through four real-world contexts. The personal context focuses on daily activities and individual self-management, such as financial management, health, or recreation. The work context relates to professional tasks, including measurement, accounting, and work-related decision-making. The social context addresses community issues and large-scale public policies, while the scientific context links mathematics to natural phenomena, health, and technology. These dimensions provide a framework for identifying and analyzing mathematical literacy among preservice teachers.

Previous studies have explored students' mathematical literacy and teachers' practices. For instance, Sulistyani et al. (2024) investigated junior high school mathematics teachers' understanding of problem contexts and content, as well as

activities that support mathematical literacy. Jupri and Rosjanuardi (2020) analyzed teachers' understanding of mathematical literacy problems. However, less attention has been given to preservice teachers' conceptions of mathematical literacy. In Indonesia, most research focuses on measuring students' literacy levels rather than understanding how preservice teachers conceptualize literacy-oriented teaching. Some studies, such as Murdy and Ekawati (2021), measured students' mathematical literacy using Indonesian cultural contexts; Aisyah and Juandi (2022) described Indonesian students' mathematical literacy over the last decade; and Fauzi et al. (2024) conducted a case study on mathematical literacy in elementary schools in Bandung.

Preservice teachers' conceptions of mathematical literacy questions are crucial because these conceptions directly influence the types of tasks they select, adapt, or design for classroom instruction. Preservice teachers' understanding of what constitutes a mathematical literacy task determines whether learning activities emphasize meaningful engagement with real-world contexts, reasoning, and interpretation, or remain focused on routine procedural exercises. When preservice teachers hold limited conceptions of mathematical literacy, they may unintentionally design tasks that appear contextual but do not truly engage students in mathematical reasoning or problem-solving (Rianasari & Guzon, 2024). Consequently, students' opportunities to develop mathematical literacy are constrained.

Previous research has identified several conception-related challenges among teachers and preservice teachers. Studies report difficulties in distinguishing authentic real-world contexts from superficial word problems, limited understanding of the variety of PISA contexts, particularly social and scientific contexts and an overemphasis on content-related aspects at the expense of processes such as formulating, interpreting, and reasoning mathematically (Jupri & Rosjanuardi, 2020; Sulistyani et al., 2024). In addition, preservice teachers often focus on identifying mathematical topics (geometry or arithmetic) rather than recognizing how tasks support literacy-oriented activities, such as modeling, argumentation, and interpretation. These conception problems suggest that preservice teachers may recognize mathematical content but struggle to holistically identify mathematical literacy tasks as defined in the PISA framework.

Given this gap, there is a need to explore how preservice teachers conceptualize and identify mathematical literacy tasks, particularly in relation to the contexts, content, and activities emphasized in the PISA framework. This study aims to examine preservice mathematics teachers' understanding of mathematical literacy by describing their ability to identify mathematical literacy questions in terms of: (1) the context and content of the questions, and (2) the activities that support mathematical literacy.

Method

Data for this study were collected using a survey method within a descriptive research design. The survey was administered via Google Form during February and March 2025. The participants comprised 176 preservice mathematics teachers, including 66 students from a private university and 110 students from a public university, both located in Yogyakarta, Indonesia.

The research instrument was a 15-item questionnaire adapted from the instrument developed by Sulistyani et al. (2024), which was designed to examine teachers' understanding of mathematical literacy tasks based on the PISA framework. The original instrument had undergone content validation by experts in mathematics education and was reported to be valid for measuring teachers' understanding of mathematical literacy contexts, content, and activities. The adaptation process in this study involved several stages. First, the original items were reviewed to ensure alignment with the objectives of the present study, particularly the focus on preservice teachers rather than in-service teachers. Second, minor modifications were made to the wording of several items to suit the preservice teacher context while maintaining the original constructs related to context, content, and activities of mathematical literacy. Third, the adapted items were mapped onto the PISA dimensions to ensure conceptual consistency and coverage. The collected data were analyzed descriptively by calculating the percentage of responses for each closed-ended item. A summary of the questionnaire indicators and the corresponding data analysis techniques is presented in Table 1.

Table 1. Questionnaire Item and Analysis Method

Questionnaire	Quantities	Analysis method
Identity	4 questions	Calculate the percentage of responses for each answer choice
Part 1: Identify the context and content of mathematical literacy questions	8 closed questions	Calculate the percentage of responses for each answer choice
Part 2: Identify the activities to support mathematical literacy	3 closed questions	Calculate the percentage of responses for each answer choice

Findings and Discussion

The survey results indicate that the majority of respondents were preservice mathematics teachers, with 5 students in the 8th semester, 55 students in the 6th semester, and 116 students in the 4th semester, totaling 176 participants. Regarding professional development experience, 122 respondents reported that they had never attended any seminar or training on mathematical literacy, while the remaining participants had previous exposure. In terms of familiarity with the concept of mathematical literacy, only 16 respondents had never heard the term, whereas 160 were already familiar with it. These findings suggest that while most preservice teachers are aware of the concept of mathematical literacy, a significant proportion have had limited practical engagement or training in this area.

In this study, four stimuli were adopted based on the research by Sulistyani et al. (2024). The stimuli are as follows: 1) A picture of the Ampera Bridge is provided, and it is known that the height of a car is 1.5 meters. Participants are asked to estimate the height of the Ampera Bridge and explain how they arrived at their estimate. 2) A bar chart showing Jakarta's climate data is provided, which includes rainfall data (blue bars) and temperature data (red line graph). Each month is represented by a single value indicating temperature. For example, in November, the rainfall is 225 mm, and the temperature is 27°C. Alex claims that 225 mm

represents the mode, while Benii claims it represents the mean. Participants are asked to determine who is correct and explain their reasoning. 3) “My Plate” scenario: Sabrina, an adult, plans a meal following Indonesia’s Ministry of Health balanced nutrition guidelines, which recommend 150 g of rice (or 300 g potatoes, or 75 g dry noodles) per meal. Given the available foods at home and her portion choices, participants are asked to analyze whether her meal aligns with the guidelines. 4) A graph showing the average height growth of male and female adolescents in the Netherlands in 1996 is presented. Participants are asked to interpret and analyze the data.

The responses related to the mathematical literacy content are presented in the following diagram. This diagram illustrates how participants identified the real-world contexts embedded in the given mathematical tasks.

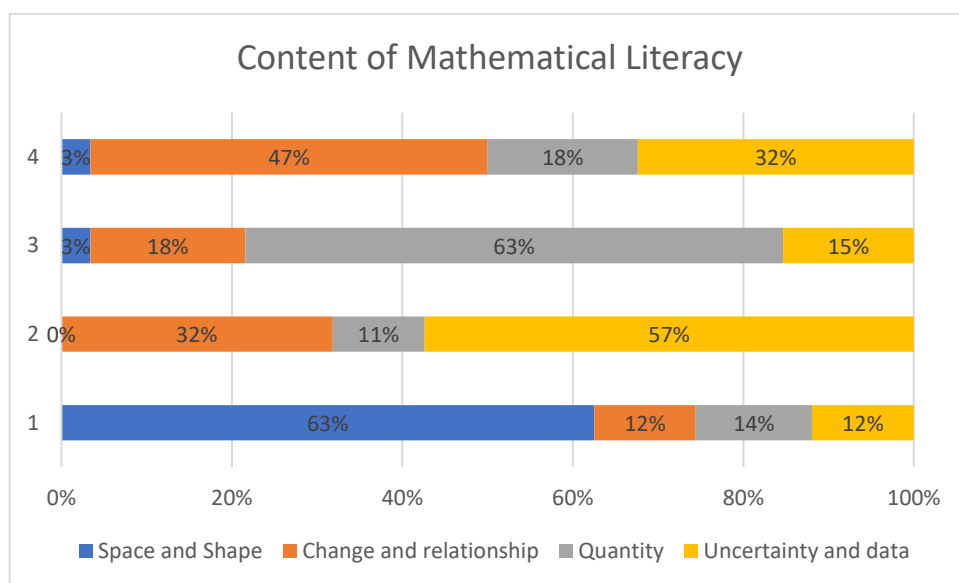


Figure 1. Data on PST Responses to the Content of Mathematical Literacy

Stimulus 1 was categorized under the content domain space and shape, stimulus 2 under uncertainty and data, stimulus 3 under quantity, and stimulus 4 under change and relationship. For Stimulus 1, which required estimating the height of the Ampera Bridge, the majority of preservice teachers accurately identified the corresponding content domain as space and shape. A smaller proportion, however, classified the item as belonging to change, relationship, quantity, or uncertainty and data. The high rate of correct classification may be attributed to the presence of supporting visual information, including an illustration of a car and the bridge, which likely facilitated participants’ interpretation of the mathematical features of the task.

Stimulus 2 corresponds to the uncertainty and data content domain. Most preservice teachers were able to identify this correctly; however, 32% misclassified it as change and relationship. Although the stimulus included both a bar chart and a line graph, this result suggests that some preservice teachers remain insufficiently familiar with tasks involving data representation. Stimulus 3, which presents the “My Plate” scenario, falls under the quantity content domain. A majority of participants (63%) classified the item correctly, yet it is noteworthy that 18%

categorized it as a change and a relationship. This misclassification may be due to the presence of multiple food components within the task, leading some preservice teachers to associate the problem with relationships among variables rather than with quantitative reasoning.

Stimulus 4, which presents data on adolescent growth, displays a graph comparing the average height of male and female adolescents across different ages. Based on this stimulus, the majority of preservice teachers identified the content domain as change and relationship; however, 32% classified it as uncertainty and data. This misidentification likely occurred because the information was presented in a graphical format, leading some participants to associate the task primarily with data representation rather than with patterns of change. The data indicate that preservice teachers were generally able to identify quantity, space, and shape, and uncertainty and data within the given tasks. However, some of them appeared to experience difficulty recognizing content related to change and relationships.

The responses related to the mathematical literacy contexts are presented in the following diagram.

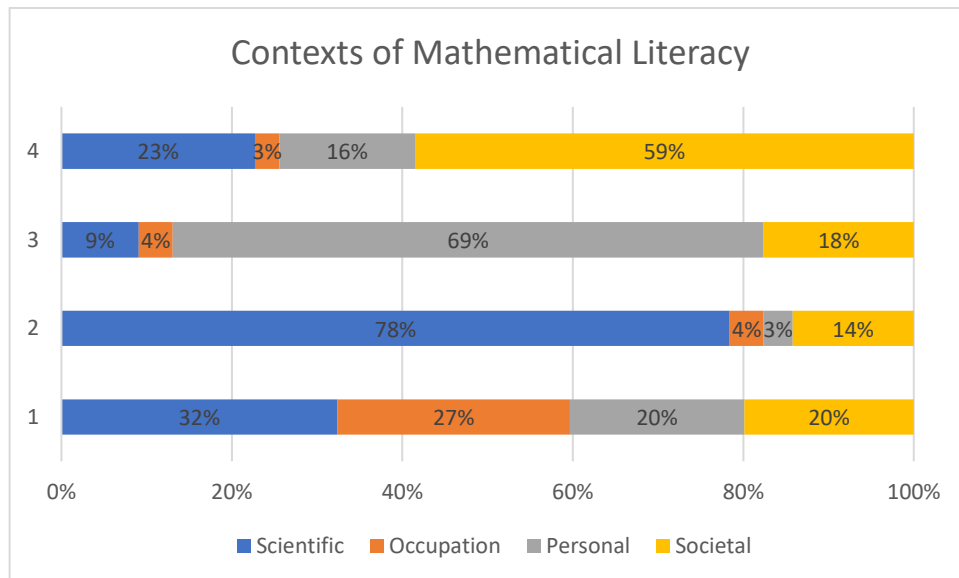


Figure 2. Data on PST Responses to the Content of Mathematical Literacy

Regarding the contexts presented in Figure 2, each stimulus was designed with a specific context classification: Stimulus 1 with a Societal context, Stimulus 2 with a Scientific context, Stimulus 3 with a Personal context, and Stimulus 4 with a Scientific context. The results of the questionnaire analysis indicate that preservice teachers were generally able to classify the context correctly for Stimulus 2 and Stimulus 3. The data show clear variation in preservice teachers' ability to identify the intended contexts in mathematical literacy tasks. Stimulus 2, designed within a Scientific context, was correctly identified by 78% of respondents. Similarly, Stimulus 3, which represented a Personal context, was accurately recognized by 69% of respondents, indicating that the contextual cues in both items were sufficiently explicit and unambiguous.

In contrast, misinterpretations were observed in Stimulus 4 and Stimulus 1. Although Stimulus 4 was intended to represent a Scientific context, the majority of

respondents (59%) instead classified it as Societal. Scientific contexts typically involve issues such as weather or climate, ecology, medicine, astronomy, or genetics (Delima et al., 2022). However, the item in Stimulus 4 presented data related to human height, which may have caused preservice teachers to perceive it as less representative of a scientific phenomenon, leading to confusion.

A similar pattern appeared in Stimulus 1, originally designed within a Societal context. Many respondents categorized it instead as Scientific (32%) or Occupation (27%), with only 20% correctly identifying the Societal context. This misclassification may be attributed to the inclusion of elements related to estimating the height of a bridge, which respondents perhaps associated with scientific or technical domains rather than societal issues. Taken together, these findings suggest that preservice mathematics teachers still experience difficulties in accurately identifying contexts within mathematical literacy tasks, particularly when contextual boundaries are subtle or when the narrative includes overlapping contextual elements.

The second focus of this study concerns activities in mathematics learning that facilitate mathematical literacy. Activity 1 involved the teacher distributing brochures about fuel-efficient cars, which included data on prices and available features. Students were asked to discuss and make a decision regarding which car to purchase in order to maximize fuel efficiency while keeping costs affordable. Activity 2 presented an image of a television along with its dimensions, and students were asked to calculate the area of the television screen. Activity 3 provided data in the form of a pie chart showing greenhouse gas emissions in 2019, and students were tasked with identifying the information conveyed by the chart, including which gas had the greatest impact.

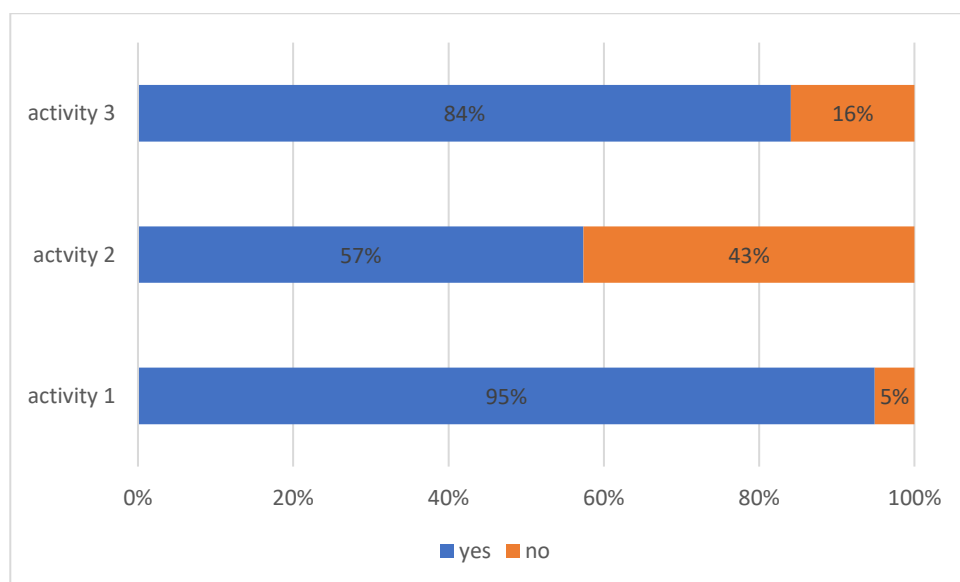


Figure 3. Data of PST responses to the Activities That Support Mathematical Literacy

Based on the data, preservice mathematics teachers demonstrated very strong ability in identifying activities that support mathematical literacy (Positive Recognition). This was particularly evident in Activity 1 and Activity 3, where the

correct response was “Yes”. In Activity 1, the accuracy rate reached the highest level at 95%, while in Activity 3, accuracy was 84%. These high percentages indicate that when a mathematics activity is designed with strong literacy characteristics, such as a clear real-world context, preservice teachers are able to recognize it easily and correctly.

However, the most critical finding emerged in Activity 2, where a significant misconception (False Positive) was observed. The correct answer indicated that this activity did not support literacy (“No”), yet 57% of respondents answered “Yes”. This means that more than half of the preservice teachers failed to distinguish between routine/procedural mathematics activities and literacy-oriented activities. They tended to assume that any mathematics activity represented literacy, even if the activity lacked an authentic real-world context or sufficient reasoning processes. Only 43% of respondents were able to correctly identify that the activity did not meet the criteria for mathematical literacy.

Overall, these data suggest that preservice teachers possess good competence in recognizing “what constitutes literacy” (correct examples), but remain weak in distinguishing “what does not constitute literacy” (incorrect examples). The response pattern in Activity 2 highlights that the main challenge in current preservice teacher education is not in understanding the definition of literacy, but rather in the ability to differentiate. Without the skill to sharply distinguish between routine tasks and literacy-oriented tasks, preservice teachers risk presenting lessons they perceive as literacy-based, even though they are actually standard procedural exercises.

The findings of this study are consistent with previous research indicating that preservice teachers often possess fragmented conceptions of mathematical literacy. Similar to the results reported by Jupri and Rosjanuardi (2020) and Wijaya (2016), a substantial number of preservice teachers in this study were unable to distinguish between routine procedural tasks and genuine literacy-oriented activities. This misconception was particularly evident in Activity 2, where more than half of the respondents incorrectly identified a purely procedural task as supporting mathematical literacy. Comparable results were reported by Melissa and Kristanto (2024), who found that prospective mathematics teachers tend to demonstrate stronger procedural numeracy knowledge than contextual reasoning and interpretation, suggesting that superficial characteristics of tasks often dominate their judgments.

In terms of content identification, preservice teachers demonstrated stronger performance in recognizing quantity, space, and shape, and uncertainty and data, while experiencing difficulty with change and relationship. This pattern aligns with the findings of Sulistyani et al. (2024) and Fuentes et al. (2014), who reported that teachers tend to focus on static mathematical content rather than on dynamic relationships among variables. The misclassification of Stimulus 4 further suggests that graphical representations alone often lead preservice teachers to associate tasks with data handling, even when the core mathematical idea involves change over time, as also noted by Stacey (2011). Similar misconceptions have been documented in studies on statistical literacy, where teachers commonly interpret graphs as indicators of data analysis rather than representations of variation and change (Watson & Callingham, 2002; Beswick et al., 2012).

Regarding context identification, the confusion between societal and scientific contexts observed in this study reflects the challenges highlighted in the PISA framework (OECD, 2019, 2023), where contextual boundaries are often subtle and overlapping. Without explicit training, preservice teachers may rely on surface features of tasks rather than on the underlying purpose of the context. This finding is consistent with previous studies involving in-service teachers in Indonesia, which reported that teachers often equate mathematical literacy with contextual or word problems and experience difficulty distinguishing between social, scientific, and occupational contexts (Melissa et al., 2024). A similar pattern has also been observed across disciplines, as Limiansih et al. (2023) found that teachers' perceptions of scientific literacy tend to emphasize content mastery rather than contextual reasoning and decision-making.

These findings are further supported by research emphasizing that realistic contexts do not automatically imply authenticity in mathematical literacy tasks. Palm (2008) and Kaiser and Schwarz (2010) highlighted that tasks may appear realistic yet still function as routine procedural exercises, which may explain the false-positive responses observed in Activity 2. Moreover, the difficulty in recognizing social contexts aligns with Skovsmose's (2011) argument that critical and societal dimensions of mathematics are often underrepresented in teacher education programs, leading preservice teachers to overlook the social purposes embedded in mathematical tasks.

Importantly, the findings of this study underscore the necessity of moving beyond descriptive research toward intervention-oriented studies that focus on enhancing preservice teachers' capacity to design mathematical literacy tasks and to develop lesson plans that explicitly promote students' mathematical literacy. As future mathematics teachers, preservice teachers need systematic opportunities to engage in designing, analyzing, and revising literacy-oriented tasks, as well as in constructing lesson plans that integrate meaningful contexts and reasoning processes. Moreover, teacher education programs play a crucial role in ensuring the continuity between preservice preparation and future classroom practice. Prior intervention studies have demonstrated that pedagogical approaches such as Realistic Mathematics Education (RME) and problem-based learning (PBL) can effectively support the development of numeracy and mathematical literacy (Ramadhani & Melissa, 2024; Melissa et al., 2024). Embedding such approaches into preservice teacher education programs may serve as a critical foundation for preparing teachers who are capable of fostering students' mathematical literacy in classroom practice.

Conclusion

In conclusion, this study shows that preservice mathematics teachers generally demonstrate adequate foundational understanding of mathematical literacy, particularly in identifying content domains such as space and shape, quantity, uncertainty, and data, as well as recognizing activities with explicit real-world contexts. Nevertheless, important challenges persist in identifying content related to change and relationship, distinguishing between overlapping contextual domains—especially societal and scientific contexts—and differentiating routine procedural activities from authentic literacy-oriented tasks. These findings indicate that preservice teachers tend to rely on surface features of tasks rather than on

deeper reasoning, dynamic relationships, and contextual purposes that characterize mathematical literacy. Thus, while preservice teachers possess initial awareness of mathematical literacy, they require targeted support within teacher education programs to strengthen their ability to critically analyze, design, and implement mathematical literacy tasks and lesson plans that genuinely foster students' mathematical reasoning, problem-solving, and real-world decision-making skills.

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FROM *RATIO STUDIORUM* TO IGNATIAN PEDAGOGY IN THE ERA OF ARTIFICIAL INTELLIGENCE

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Received: 6 November 2025; Accepted: 22 December 2025

Abstract

This theoretical paper examines the enduring relevance of Jesuit educational philosophy by tracing its development from the *Ratio Studiorum* of 1599 to the Ignatian Pedagogical Paradigm (IPP) of 1993 within the horizon of the Artificial Intelligence (AI) era. Using a historical-textual analysis of foundational Jesuit educational documents alongside a systematic conceptual synthesis of contemporary literature on Ignatian Pedagogy and educational technology, the study explores two guiding questions: (1) How does a four-century-old Jesuit educational tradition remain significant in the age of AI? and (2) What distinctive contributions can Jesuit pedagogy offer within technologically mediated learning environments? The findings indicate that the core elements of the IPP – context, experience, reflection, action, and evaluation – provide a humanistic and ethically grounded framework that counters the tendencies toward superficiality, depersonalization, and algorithmic reductionism associated with AI-driven educational models. The paper argues that Ignatian Pedagogy offers educators a vital model for digital discernment, maintaining the primacy of conscience, relational depth, reflection, and the formation of persons for others. These insights highlight the continuing importance of Jesuit education in shaping moral, reflective, and critically aware learners in a rapidly evolving technological world.

Keywords: artificial intelligence, educational philosophy, Ignatian pedagogical paradigm, Jesuit education, *Ratio Studiorum*

Introduction

The Jesuit educational tradition is one of the most enduring pedagogical lineages in the world, rooted in the Spiritual Exercises of St. Ignatius of Loyola (1522–1524) and formalized in the “*Ratio atque Institutio Studiorum Societatis Iesu*” (1599). Across centuries, Jesuit education has sought to integrate intellectual excellence, moral integrity, and spiritual depth in forming individuals capable of contributing to society with wisdom and discernment.

The rapid rise of Artificial Intelligence (AI) is reshaping educational landscapes, introducing new possibilities for personalization, efficiency, and accessibility. Yet it also raises pressing concerns: erosion of human reflection, algorithmic shaping of behavior, depersonalization of learning, and biases embedded within computational systems. These realities underscore a foundational question: what does human formation mean in the age of intelligent machines?

This paper contributes to an emerging global conversation by positioning the Ignatian Pedagogical Paradigm (IPP) – with its emphasis on context, experience,



reflection, action, and evaluation – as a critical resource for forming reflective, ethical, and relational learners within AI-mediated learning environments. Ignatian pedagogy, grounded in discernment, relationality, reflective depth, and *cura personalis*, offers a countercultural response to an era characterized by speed, automation, and algorithmic influence (Nicolás, 2011).

To trace this relevance, the paper first examines the humanistic foundations of the Ratio Studiorum, explores the renewal of Jesuit pedagogy in the 1993 IPP document, and synthesizes contemporary scholarship. It then analyzes the challenges and possibilities presented by AI and evaluates how Ignatian pedagogy provides a transformative framework for navigating digital transformation without sacrificing the essence of human formation.

Method

This study employs a theoretical and conceptual research design, drawing on historical-textual analysis and integrative literature synthesis. Rather than presenting empirical data, it synthesizes classical Jesuit educational texts (including the Ratio Studiorum and the Ignatian Pedagogical Paradigm), scholarly interpretations across diverse cultural contexts, and contemporary literature on artificial intelligence in education. Through critical analysis and thematic integration, the paper examines how Ignatian Pedagogical principles intersect with the ethical and epistemological challenges of AI-mediated learning. This methodological approach allows for a nuanced exploration of continuity, adaptation, and innovation within the Jesuit education tradition.

Data Sources

The analysis is based on two categories of literature:

1. Primary historical documents of Jesuit education
 - Ratio Studiorum (1599).
 - Characteristics of Jesuit Education (ICJE, 1986).
 - Ignatian Pedagogy: A Practical Approach (ICAJE, 1993).

These documents articulate the philosophical, spiritual and pedagogical principles underpinning Jesuit education.

2. Contemporary Peer-Reviewed
 - Studies on Ignatian Pedagogical Paradigm (Hayes, 2006; McAvoy, 2013; Connor, 2014; Mummadi, 2021).
 - Historical and philosophical analysis of Jesuit education (O'Malley, 2000; Mesa, 2017; Lorenz, 2017).
 - Artificial Intelligence and digital ethics (Sadiku et al., 2021; Pedro et al., 2019, Roll & Wylie, 2016; UNESCO, 2019).

Literature was selected for its relevance to the paper's guiding questions and its contribution to contemporary debates on pedagogy, formation, and educational technology.

Analytic Procedures

The conceptual methodology proceeded through three stages:

Stage 1: Historical – Textual Analysis

Historical sources were examined to identify the foundational pedagogical principles of the Ratio Studiorum and their reinterpretation in the 1993 Ignatian Pedagogical Paradigm. This step mapped the historical continuity of Jesuit educational principles.

Stage 2: Thematic Literature Synthesis

Key themes across IPP scholarship – cura personalis, reflection, relationality, adaptability – were synthesized to articulate patterns, tensions, and insights within contemporary Jesuit pedagogy. This synthesis established the conceptual strengths and limitations of the IPP.

Stage 3: Conceptual Integration with AI Literature

Insights from AI scholarship were compared with Ignatian Pedagogical Principles to evaluate opportunities, risks, and the potential for “Ignatian digital discernment” within AI-mediated education. This integrative approach allowed a nuanced assessment of how Ignatian Pedagogy can inform responsible engagement with AI technologies. This conceptual methodology provides a robust framework for evaluating how centuries-old pedagogical tradition remains relevant amid technological transformation.

Findings and Discussion

The Ratio Studiorum (1599): Humanistic Roots of Jesuit Education

The “Ratio atque Institutio Studiorum Societatis Iesu, promulgated on January 8, 1599, stands as the first comprehensive and systematized code of Jesuit education. Developed over fifty years of experimentation, reflection, and iterative refinement, the Ratio represents a synthesis of Jesuit educational practice grounded in the Spiritual Exercises and the Society’s apostolic mission (Farrell, 1938).

The drafting process unfolded in two major phases: an initial 36-year period of gathering and testing materials across Jesuit schools, followed by fourteen years of revision, clarification, and codification under the leadership of Superior General Claudio Aquaviva (Padberg, 2007; O’Donnell, 2007). The resulting document provided an unprecedented degree of uniformity and coherence across Jesuit institutions worldwide.

Farrell (1938) identifies four key elements structuring the Ratio Studiorum:

1. Administration – defining responsibilities of key officials such as the Provincial, Rector, and Prefect of Studies.
2. Curriculum – establishing a sequenced course structure in theology, philosophy, rhetoric, grammar, and the humanities.
3. Method – outlining precise expectations for lessons, classroom engagements, disputations, and examinations.
4. Discipline – detailing norms for student behavior, order, and moral development.

The Ratio sought not merely to transmit knowledge, but to form eloquent, morally grounded, intellectually capable leaders, summarized in the classical ideal: *ad perfectam enim eloquentiam informat* – “an education toward perfect eloquence.” Ahmadian (2014) interprets the Ratio through the lens of modern pedagogy, emphasizing its linguistic rigor – particularly the mastery of Latin, Greek, and Hebrew – and its commitment to rhetorical formation. Upon completing Jesuit studies, students emerged as magister, doctor, teacher, or professor in the fullest sense (Ahmadian, 2014).

Contemporary scholarship, however, highlights its deeper spiritual and anthropological foundations. Lorenz (2017) argues that the Ratio is not simply an academic manual but a spiritual framework aiming at integral human formation. It embodies a “way of proceeding” that integrates intellectual depth, ethical formation, and spiritual discernment.

Beginning in the 1960s, Jesuit educators questioned whether the Ratio Studiorum remained adequate in a rapidly changing world (Duminuco, 2000). The rise of new educational theories, global cultural shifts, and emerging technologies – including the first articulation of “Artificial Intelligence” by John McCarthy in 1956 (Walsh, 2025) – intensified calls for renewal. These developments set the stage for a new articulation of Jesuit pedagogy in the late 20th century.

In response to such critical situations about the Ratio’s contemporary application, the former Jesuit General, Pedro Arrupe, established the International Commission on the Apostolate of Jesuit Education (ICAJE) that developed a new articulation of Jesuit educational principles in 1986, entitled *The Characteristics of Jesuit Education*, which coincided with the 400th anniversary of the original Ratio Studiorum.

Despite the positive reception of the *Characteristics* document (Duminuco, 2000), Jesuit educators, lay teachers, professors and administrators expressed a need for practical guidance on how to implement its ideals in everyday teacher-student interactions in bridging the gap between theory and practice (Unpublished *Archivum Historicum Societatis Iesu*, cited in Duminuco, 2000).

Ignatian Pedagogical Paradigm (1993): Renewal of the Tradition

In response to the need for a more contemporary and actionable educational framework, the International Commission on the Apostolate of Jesuit Education (ICAJE) published *The Ignatian Pedagogical Paradigm: A Practical Approach* in 1993. This document translated the principles of the *Characteristics of Jesuit Education* (1986) into a practical, student-centered methodology.

A distinctive feature of the IPP is its grounding in the Spiritual Exercises, emphasizing that education seeks to form persons who are “men and women for others” through intellectual, moral, and spiritual growth. As Kolvenbach (ICAJE, 1986) notes, Jesuit education aims at holistic formation, integrating academic excellence with conscience, compassion, and service.

Core Elements of the IPP

1. Context

Understanding the learner’s background, environment, disposition, and needs. Education begins with attention to the whole person (IPP, nn. 33–42).

2. Experience

Learning engages the full person – mind, heart, imagination, and will. Students are invited to “taste things internally” through meaningful encounters (IPP, nn. 42–46).

3. Reflection

The distinguishing mark of Ignatian pedagogy. Learners examine meaning, motivations, and implications of experience through memory, understanding, feeling, and imagination (IPP, nn. 47–58).

4. Action

Reflection leads to choices, decisions, and transformative action – moving learning from theory to lived commitment (IPP, nn. 59–62).

5. Evaluation

Goes beyond academic metrics to assess holistic growth, ethics, and personal development (IPP, nn. 63–67).

The Ignatian Pedagogy (1993) outlines a learning process that begins with students’ personal experiences, guided by the teachers to connect to prior knowledge, feelings, and values. The teachers initiate the students in reflection, to engage memory, imagination, and feelings, to uncover deeper meanings and connections. This reflective process shapes students’ consciousness, attitudes, and values, ultimately leading to action. This process is described as a spiral movement (Hayes, 2006), with teachers facilitating the ongoing cycle of experience, reflection, and action. Teachers accompany learners in this cycle, fostering deeper awareness and promoting discernment.

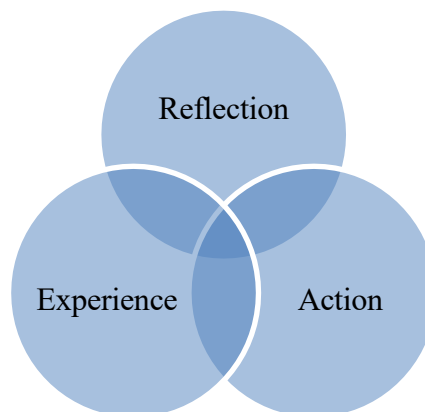


Figure 1 Ignatian Paradigm

The IPP thus renews Jesuit education for modern contexts, offering principles adaptable across cultures, disciplines, and historical moments – including today’s digital age.

Synthesis of Contemporary Ignatian Pedagogical Paradigm (IPP) Scholarship and Its Relevance in the Era of Artificial Intelligence

In an AI-driven educational environment defined by speed and overstimulation, IPP stands as a radically countercultural framework. IPP promotes depth over speed: where AI encourages rapid information processing, Ignatian Pedagogy insists on slow, attentive engagement shaped by reflection (Hayes, 2006; McAvoy, 2013). Moreover, IPP cultivates interiority in a distracted age dominated by algorithmic nudges and constant digital stimuli. Ignatian pedagogy draws learners inward toward conscience, discernment, and spiritual depth – forming resilient individuals capable of navigating digital environments without losing their humanity (Ignatian Pedagogy, 1993; Baskara, 2023). Thus, the following review of contemporary empirical and conceptual studies reveals four major insights into the strengths, tensions, and evolving applications of the IPP.

Hayes (2006) offered one of the earliest empirical examinations of IPP in Jesuit schools in Australia, demonstrating how *cura personalis* deepened interpersonal relationships and enhanced student engagement. Yet he also identified a persistent tension between spirituality and institutional structure: while some teachers embraced IPP as an authentic expression of Ignatian Spirituality, others perceived it as a top-down administrative mandate rather than a living pedagogy. Hayes' nuanced analysis of IPP's paradoxical, relational, spiritual, and political dimensions was insightful, but it devoted limited attention to the formative processes shaping teachers' understanding of IPP. McAvoy (2013) addressed this gap by foregrounding faculty formation. Her two-phase intervention in Jesuit higher education revealed notable improvements in teachers' intentionality, student engagement, and reflective assessment practices. However, the study relied on a small, short-term sample and self-reported data without longitudinal follow-up, leaving the sustainability of transformation uncertain. Connor (2014) expanded IPP's application through the Interdisciplinary Studies Assessment (ISA) model, integrating professional experience with academic reflection among adult learners. By linking reflection and discernment, Connor demonstrated IPP's potential to foster lifelong learning and professional ethics. Nevertheless, the study lacked a comparative framework to evaluate IPP alongside non-Ignatian pedagogies. Mauri et al. (2015) brought IPP into business and management education, contrasting traditional case methods with an Ignatian experiential approach. Their analysis found that both sharpen analytical reasoning, but only the Ignatian model systematically cultivated ethical discernment and reflective judgment. Despite its theoretical contribution, the work remained largely conceptual and lacked empirical grounding.

In the field of language and literature education, González-Aller Mackinlay and Hernández (2017) emphasized IPP's adaptability, integrating literary interpretation with moral and spiritual reflection. Yet the study did not include empirical validation, and some students expressed discomfort with explicitly value-laden reflection. Mummadi's (2021) doctoral research in India confirmed that the five elements of IPP – Context, experience, reflection, action, and evaluation – collectively promote teachers' pedagogical and spiritual growth. However, inconsistent institutional support and insufficient teacher training hindered effective implementation. In the Philippines, Atienza and Go's (2019) model of Learning by Refraction reinterpreted IPP through three relational axes: learner-teacher, teacher-

world, and learner-world – anchored in the “6 Es”: Empathy and Empowerment, Expertise and Enthusiasm, Engagement and Excellence. Though conceptually innovative, its classroom effectiveness remains to be systematically tested. Similarly, Katindoy’s (2019) interpretive review reinforced the teacher’s role as a designer, facilitator, and coach of meaningful learning experiences but lacked empirical evidence. At Universitas Sanata Dharma, Anggadewi et al. (2019) observed that IPP fosters lecturers’ interpersonal development, empathy, and contextual awareness. In Timor-Leste, Pereira (2018) reported positive student perceptions of IPP integration but highlighted the need for sustained teacher formation and institutional coherence. Taken together, these studies illustrate a recurring challenge: while IPP remains conceptually robust and widely valued, its effectiveness varies significantly across contexts and depends largely on consistent teacher formation, contextual sensitivity, and structural support.

Synthesis of Contributions

Despite methodological and contextual differences, scholars converge on several core insights regarding IPP’s educational significance. First, IPP emerges as a holistic pedagogical framework integrating cognitive, affective, ethical, and spiritual dimensions of learning. Hayes (2006) and McAvoy (2013) demonstrate how *cura personalis*, reflective practice, and intentional pedagogy deepen both engagement and relational quality. Connor (2014) and Figueiredo et al. (2015) extend this integrative approach to professional and managerial learning environments. Second, reflection and discernment stand at the paradigm’s core. Across Connor’s ISA model, Mauri et al.’s experiential design, and Atienza and Go’s (2019) Learning by Refraction, reflection bridges experience and action, transforming learning into ethical and moral commitment. Third, IPP proves to be context-responsive and adaptive. From Jesuit schools in Australia and India (Hayes, 2006; Mummadi, 2021) to San Francisco, Manila, Yogyakarta, and Timor-Leste (Connor, 2014; Atienza & Go, 2019; Anggadewi et al., 2019; Pereira, 2018), IPP evolves through inculturation, responding creatively to local realities rather than imposing uniform methods. Finally, faculty and staff formation remain indispensable. McAvoy (2013), Mummadi (2021), Anggadewi et al. (2019), and Pereira (2018) underscore that IPP’s vitality depends on educators’ personal and communal appropriation of its spiritual and pedagogical principles.

Emerging Themes: IPP in a 21st-Century Horizon

Three key themes emerge as particularly relevant in the age of artificial intelligence:

1. Relational and Ethical Formation – IPP foregrounds the triadic relationships of learner-teacher, teacher-world, and learner-world (Atienza & Go, 2019; Katindoy, 2019). It cultivates empathy, empowerment, and ethical awareness – qualities that counterbalance the impersonal and algorithmic logic of AI systems.
2. Reflective and Critical Engagement – IPP’s emphasis on reflection moves learners from experience toward interpretation and moral action. This cultivation of discernment and moral imagination is indispensable in an information-saturated digital culture often marked by superficiality and uncritical consumption.

3. Contextual and Adaptive Pedagogy – IPP’s inherent flexibility enables educators to respond meaningfully to technological and cultural transformation (Mummadi, 2021; Pereira, 2018). Its adaptability positions Jesuit pedagogy to engage productively with the ethical and epistemological challenges posed by AI.

A persistent cross-cutting issue remains the gap between the ideal and implementation. Yet this tension – between aspiration and practice – constitutes the dynamic core of Jesuit education. It continually renews IPP’s relevance, ensuring that Ignatian pedagogy remains both humanizing and transformative in an increasingly digital world.

Discussion: Bridging Ignatian Pedagogy and AI-Mediated Education

The synthesis of historical texts, Jesuit educational documents, and contemporary scholarship reveals several key insights into the enduring relevance of Jesuit pedagogy in an era increasingly shaped by Artificial Intelligence (AI). These insights represent the conceptual “findings” of this theoretical study.

1. Ignatian Pedagogy Offers a Holistic and Humanizing Framework Beyond Algorithmic Logic

While AI-driven educational platforms optimize efficiency and personalization, they often prioritize data-driven outcomes over integral human development. By contrast, the Ignatian Pedagogical Paradigm (IPP) integrates cognitive, affective, moral, spiritual, and relational dimensions of learning. Its core elements – context, experience, reflection, action, and evaluation – offer a humanistic counterbalance to algorithmic thinking by insisting that education is not merely about acquiring skills but forming the whole person. This holistic vision aligns with the Jesuit mission of forming “persons for others,” whose education leads to ethical discernment, deep understanding, and service-oriented action.

2. Reflection and Discernment Are Indispensable in Digital Learning Environments

Reflection stands at the heart of Ignatian Pedagogy. Across studies – from Hayes (2006) to Connor (2014) - reflection emerges as the transformative moment in the learning cycle. In contemporary contexts marked by rapid information flow, digital overload, and algorithmic nudges, reflection becomes even more critical. Rather than passive consumption, Ignatian Pedagogy promotes critical awareness, enabling students to recognize biases, question technological assumptions, and evaluate the ethical implications of AI. Reflection becomes the antidote to superficiality and digital distraction.

3. IPP Strengthens Relationality Amid Increasing Technological Mediation

AI systems can simulate personalized interactions, yet they cannot replicate *cura personalis* - the deep, relational, empathetic care central to Jesuit education. The relational dynamics of teacher-student accompaniment, authentic dialogue, and ethical mentoring remain irreplaceable for moral and spiritual formation. Even as AI becomes integrated in classrooms, teachers remain the primary agents of accompaniment, helping students navigate emotional, ethical, and spiritual dimensions of their learning.

4. IPP's Adaptability Supports Creative Engagement with Emerging Technologies

IPP has demonstrated remarkable adaptability across diverse cultural contexts – Australia, India, Indonesia, the Philippines, and Timor-Leste. This adaptability extends naturally to technological contexts as well. Its focus on context encourages educators to understand digital environments as formative spaces that shape identity, attention, and moral imagination. Rather than rejecting technology, IPP equips educators to engage AI critically and creatively.

5. The Gap Between IPP Ideals and Practice Remains a Challenge

Research consistently highlights implementation challenges: insufficient teacher formation, institutional inconsistencies, and limited integration of Ignatian Spirituality into pedagogy. In the AI era, these challenges risk becoming more pronounced if institutions adopt technology without grounding it in discernment, ethics, and *cura personalis*. Consequently, educator formation in both Ignatian Pedagogy and AI ethics is essential for sustainable, humanizing integration.

The Era of Artificial Intelligence: Challenges and Possibilities within Jesuit Education

The concept of artificial intelligence (AI) was first introduced in 1956 at the Dartmouth College Conference, where it was defined as the ability of computer systems to replicate human intelligence by performing tasks that require reasoning and learning (Sadiku, 2022). The primary goal of AI is to develop systems that emulate human cognitive functions – such as perception, decision-making, and language processing – traditionally associated with human thought (Sadiku et al., 2021). By extending human cognitive capacities into computational forms, AI now performs tasks once reserved for human intellect. Consequently, its expanding presence has begun to reshape education, influencing teaching, communication, administration, and resource management (Sadiku et al., 2021).

Applications of Artificial Intelligence in Education

AI offers unprecedented efficiency and scalability, yet it raises profound ethical concerns. Algorithmic bias reproduces structural inequities (Pedro et al., 2019; Roll & Wylie, 2016). Modern AI platforms rely on large-scale data extraction, raising issues of privacy, autonomy, and surveillance (Sadiku et al., 2021; UNESCO, 2019). From an Ignatian viewpoint, such practices risk reducing learners to data points rather than persons in formation (Kolvenbach, 2001). Thus, educators must scrutinize AI systems to ensure they genuinely serve human dignity.

AI has emerged as a transformative force in education, supporting teachers, enhancing learning experiences, and streamlining administrative processes (Sadiku et al., 2021).

1. In the Classroom:

While AI cannot replace human educators, it can significantly enhance teaching and learning. AI-powered tools assist with grading, assessment, and feedback, freeing educators to focus on mentorship and formative engagement.

Intelligent tutoring systems provide personalized academic support, particularly for learners who experience anxiety or difficulty in traditional classroom settings, thus extending access to individualized learning beyond classroom hours.

2. Personalized Learning:

Traditional education often lacks flexibility, but AI facilitates adaptive learning experiences tailored to individual learners. By analyzing performance data, AI systems design customized study plans, adjust learning pace, and provide real-time feedback. Such personalization accommodates diverse learning styles and abilities while improving accessibility, efficiency, and scalability across educational contexts.

3. Administrative Functions:

AI enhances institutional efficiency by automating repetitive administrative tasks – such as grading, scheduling, and data management – allowing educators to devote more attention to pedagogy, pastoral care, and student development.

4. Global and Universal Access:

AI promotes inclusive and borderless education by overcoming geographical and linguistic barriers. Intelligent translation tools and adaptive platforms create global classrooms accessible to learners anywhere, fostering intercultural understanding and lifelong learning.

5. Medical and Professional Education:

In health sciences, AI plays an increasingly vital role in preparing future professionals. As AI becomes integral to clinical practice, medical educators must train students to interpret, evaluate, and ethically engage with these technologies. Similarly, in business and marketing education, AI tools such as predictive analytics, content generation, and chatbots are redefining professional standards and competencies, emphasizing the need for ethical formation alongside technical mastery.

Sadiku et al. (2021) highlight the benefits of AI for students, teachers, and institutions – such as continuous access to learning, virtual mentorship, improved engagement, enhanced teacher support, cost reduction, and operational efficiency. However, they also identify significant challenges, including limited technological capacity, unresolved ethical questions, and issues of trust and accountability. AI thus presents both promise and peril while it enhances the teaching-learning process, the teacher remains irreplaceable, for authentic formation depends upon human connection and moral guidance.

Critical Commentary on Sadiku et al. (2021): Artificial Intelligence in Education

Sadiku presents AI as a transformative tool with vast potential to enhance efficiency, accessibility, and personalization in education. His analysis highlights the practical applications of AI – automated grading, adaptive learning, data-driven administration, and global digital access – all aimed at improving teaching and learning outcomes. He argues that AI can reduce educators' workload, allowing them to focus on mentoring, and that intelligent platforms can democratize learning opportunities across social and geographic boundaries.

While comprehensive, Sadiku's framework reflects a predominantly technocentric perspective that privileges technological functionality over pedagogical and ethical reflection. His analysis explains what AI can do but not what it ought to do within education. Critical concerns such as data privacy, algorithmic bias, depersonalization, and the erosion of human reflection are acknowledged only tangentially. Consequently, his account overlooks the moral and anthropological dimensions of education – the formation of conscience, empathy, and wisdom – that lie at the heart of Jesuit pedagogy.

From an Ignatian pedagogical perspective, Sadiku's work provides an entry point for deeper dialogue between technology and human formation. The Ignatian Pedagogical Paradigm (IPP) – structured around context, experience, reflection, action, and evaluation – offers a framework for discerning the ethical and formative implications of AI. In Jesuit education, technology must serve "cura personalis", the care of the whole person, fostering reflection, discernment, and social responsibility rather than mere efficiency. Thus, while Sadiku outlines the technical possibilities of AI, Ignatian pedagogy reorients the discussion toward moral discernment and human flourishing.

AI, when engaged through the Ignatian lens, becomes not simply a tool for instructional convenience but a subject of reflection and ethical formation. The key question shifts from "What can AI do for education?" to "What should AI do for humanity?" This discernment-driven approach aligns with Jesuit educational aims – to form persons of conscience, competence, and compassion capable of critical engagement with the world's emerging technologies.

AI and the Jesuit Educational Vision

The preceding applications illustrate how artificial intelligence (AI) is reshaping the landscape of knowledge production, communication, and learning. From adaptive platforms to generative models, AI promises to personalize instruction, automate assessment, and expand accessibility. Yet, as Nicolás (2011) cautioned, the rapid acceleration of technology risks contributing to a "globalization of superficiality" – a culture where instant access to information undermines depth of thought, reflection, and discernment.

The integration of AI into education thus raises pressing ethical and pedagogical questions: How can educators preserve the human capacity for reflection, empathy, and moral judgment when algorithms increasingly mediate the learning process? What happens to the relational and contemplative dimensions of education when interactions occur primarily through intelligent systems? Jesuit pedagogy responds by insisting on:

- Discernment over impulsivity
- Reflection over distraction
- Wisdom over mere information
- Relationality over individualism
- Ethical integrity over efficiency

The above response offers a counter-narrative grounded in discernment, conscience, and the formation of the whole person. It resists the reduction of education to mere data optimization by emphasizing intellectual, moral, and spiritual integration. The principle of "cura personalis" – care for the whole person

– becomes vital in this context: educators are not simply called to adopt AI tools but to humanize their use, ensuring that technology serves human dignity rather than diminishes it.

Pope Leo XIV (2025) on Education and Technology

In his 2025 address on the occasion of the 60th Anniversary of the conciliar Declaration – *Gravissimum educationis*, Pope Leo XIV articulated a vision that resonates profoundly with the Ignatian tradition:

1. Faith, culture, and life must converge within Catholic education. Schools are not merely institutions but living communities where the Christian vision permeates every discipline and encounter.
2. Education as choreography: Echoing Pope Francis, he urged educators to “bring about a new choreography that respects the dance of life by placing the human person at the center.” Authentic formation resists compartmentalization.
3. Integral humanism: Catholic education acts as leaven within the human community – fostering reciprocity, countering reductionism, and cultivating social responsibility while maintaining an orientation toward the transcendent.
4. Technology as servant, not master: Technologies must enrich learning rather than impoverish relationships. Without vision, schools risk becoming efficient yet soulless, reducing knowledge to standardization and spiritual emptiness.
5. Discernment in progress: Technological advancement is part of God’s creative plan, yet discernment is required in design, evaluation, data protection, and equitable access.
6. Human uniqueness: No algorithm can substitute the essence of education – poetry, irony, love, art, imagination, joy, and the formative power of error and discovery.
7. Ethical governance: The decisive issue is not technology itself but how it is used. AI and digital environments must protect human dignity, promote justice, and serve the common good.
8. Judicious use of technology: Education must form persons capable of harmonizing technical, emotional, social, spiritual, and ecological intelligence – placing the person before the algorithm and fostering peace, reconciliation, and solidarity.

Pope Leo XIV’s vision for Catholic education offers a framework directly applicable to AI ethics and Ignatian Pedagogy. His insistence that technology remain a ‘servant of human flourishing’ speaks directly to concerns about AI-driven depersonalization. His call for a ‘new choreography that places the human person at the center’ highlights the need for discernment in evaluating algorithms that shape students’ identities, choices, and relationships. This aligns with Ignatian principles of *cura personalis*, ethical governance, and holistic formation – affirming that AI must be subject to ongoing discernment rather than uncritical adoption. Pope Leo’s vision complements the Ignatian commitment to integral formation. Both insist that the goal of education is not technological efficiency, but human flourishing grounded in wisdom, justice, and love.

Integrating Ignatian Pedagogy in the AI Age: Humanistic Formation in a Digital World

Integrating the Ignatian Pedagogical Paradigm (IPP) into AI-driven education requires reaffirming Jesuit education's humanistic and transformative vision. The five elements of IPP – context, experience, reflection, action, and evaluation – offer an ethical and pedagogical framework for navigating digital transformation.

- Context now includes digital environments: the algorithms, interfaces, and systems that shape students' attention, cognition, and identity. Educators are invited to discern how these contexts influence formation, relationships, and the pursuit of truth.
- Experience takes on new forms as learners interact not only with teachers and peers but also with intelligent systems. Ignatian pedagogy urges critical awareness of these mediated experiences, recognizing both their potential for enrichment and their risks of alienation.
- Reflection becomes the antidote to superficiality. It enables learners to interpret technological experiences through ethical, spiritual, and social lenses - transforming passive consumption into active discernment about meaning, justice, and purpose.
- Action calls for responsible participation in shaping AI's role in society. Students formed in the Ignatian tradition become moral agents who use technology for the common good, integrating competence with conscience.
- Evaluation extends beyond academic performance to include ongoing self-assessment, moral accountability, and social responsibility within digital contexts.

Through these five elements, Jesuit education sustains its mission of forming persons of competence, conscience, compassion, commitment, and Christ-centeredness – the “Five Cs” (Characteristics of Jesuit Education, 1986) that define integral human formation. IPP thus becomes a living tradition for digital discernment, ensuring that technological progress contributes to humanization rather than depersonalization.

Conclusion

The historical development from the Ratio Studiorum (1599) to the Ignatian Pedagogical Paradigm (1993) reveals a Jesuit educational tradition capable of continuous renewal while remaining grounded in discernment, integral human formation, and spiritual depth. The emergence of Artificial Intelligence presents both unprecedented opportunities and profound ethical challenges, reshaping how knowledge is accessed, mediated, and constructed. In this rapidly evolving context, Ignatian Pedagogy offers a uniquely humanizing horizon.

While AI can enhance efficiency, personalization, and access, it cannot replicate the reflective, relational, or ethical dimensions that lie at the heart of Jesuit education. The IPP's five elements – context, experience, reflection, action, and evaluation – provide a transformative framework for digital discernment, enabling learners to navigate technological landscapes with critical awareness, moral imagination, and interior freedom.

Ignatian pedagogy promotes depth over speed, interiority over distraction, and human dignity over algorithmic reductionism. It calls educators and institutions not merely to adopt new technologies but to discern their purposes, impacts, and

alignment with the mission of forming “persons for others.” The task is not technological integration alone, but the cultivation of a moral and contemplative posture capable of engaging technology with responsibility and wisdom.

Future Directions

Moving forward, Jesuit institutions can play a leading role in shaping ethical and human- centered educational uses of AI by:

- Embedding AI ethics and Ignatian reflection into faculty and staff formation.
- Developing governance structures to ensure technology upholds dignity and justice.
- Conducting empirical research on reflective and value-oriented AI-mediated learning.
- Designing curricula that foster digital citizenship grounded in conscience and compassion.
- Forming graduates capable of using technology for the common good

In an increasingly algorithmic world, the Ignatian commitment to reflection, discernment, relational care, and justice acquires renewed urgency. The challenge – and opportunity – is to integrate innovation without surrendering the humanity at the heart of education. Jesuit pedagogy thus continues its centuries-long mission: forming individuals who think critically, act justly, and discern wisely in the service of faith, justice, and the common good.

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THE INTEGRATION OF ARTIFICIAL INTELLIGENCE IN MATHEMATICS EDUCATION: A SYSTEMATIC LITERATURE REVIEW

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Received: 5 October 2025; Accepted: 5 November 2025

Abstract

The rapid advancement of technology in the Beta generation era continually presents new developments. To keep pace, the world of education must adapt accordingly. The alignment of technological progress with the utilization of artificial intelligence (AI) in education is expected to yield positive impacts. This research aims to analyze the utilization of AI technology implemented in mathematics learning. Employing a qualitative approach with a systematic literature review method, the study draws its literature from Google Scholar, focusing on publications from the last five years (2020 – 2025). The Publish or Perish application was used by the researchers to analyze and manage scientific references. The findings indicate that the utilization of AI can assist students in comprehending concepts and optimizing classroom learning.

Keywords: artificial intelligence, education, mathematics

Introduction

Current technological advances are developing at a rapid pace. Therefore, the world of education must adapt to these advances so as not to fall behind the times. This adjustment is urgently needed for the development of education, especially mathematics education. In teaching mathematics, technological advances can be utilized to make it easier for students to understand this abstract subject, one of which is through artificial intelligence. This development is driven by the finding that educational technology in general expands learning opportunities and enables various access paths to mathematical material through a blended learning approach and personalized learning differentiation (Attard & Holmes, 2020). In the framework, AI can be interpreted as part of a technology ecosystem that provides visualization, dynamic manipulation of mathematical concepts, and alternative and more diverse feedback compared to traditional approaches (Attard & Holmes, 2020). Consequently, the argument for adapting education rests on a robust evidence base indicating that technology-enabled strategies can enhance mathematical reasoning, spatial ability, and problem-solving capabilities across diverse learner populations.

The use of AI can not only help students visualize abstract mathematical concepts into tangible concepts, but it can also strengthen students' basic understanding of mathematical material. AI technology can also be used as a learning aid that considers students' learning styles. Working in the fields of



mathematics, which emphasizes the use of digital technology, shows how tools for visualizing and manipulating mathematical concepts dynamically can accommodate variations in students' learning outcomes. Moreover, AI can serve as a complement that strengthens instruments for personalization, for example, through task recommendations, difficulty level adaptation, and feedback tailored to student responses (Attard & Holmes, 2020; Ross et al., 2025). In parallel, research on data modelling and meta-representational practices demonstrates that when students generate and critique multiple representations, they develop more sophisticated statistical thinking and reasoning about data. The emergence of construct maps and related diagnostic frameworks-contexts in which AI could facilitate real-time mapping of student thinking-further supports the view that AI-enabled visualization can scaffold mathematical understanding by making reasoning visible and actionable. Taken together, these strands suggest that strengthening foundational understanding through guided exploration of representations and their relationships.

Study Purpose and Research Question

This study aims to examine and synthesize empirical evidence on the use of artificial intelligence in mathematics education. This study also aims to gain an in-depth understanding of how artificial intelligence can help students understand abstract mathematical concepts and the use of artificial intelligence in the teaching and learning process of mathematics. The findings obtained from this study can be used as a basis for an investigation into mathematics learning methods that utilize artificial intelligence. Furthermore, the findings from this study also answer the research question: How can the use of technology in mathematics learning help students understand mathematical concepts?

Method

Search Strategy

This study utilizes keywords in searching for data sources to answer the research questions. The following keywords were used in the search:

1. Artificial intelligence, including “technology”, “ChatGPT”, and “AI.”
2. Mathematics education, including “mathematics”, “learning”, “mathematics learning”, “education”, “mathematics education”.

The use of these keywords resulted in 356 articles, which were searched using Publish or Perish software from the following databases: Springer, Elsevier, Taylor & Francis, SAGE Journal, ERIC, and JSTOR. However, only 2 articles met the exclusion and inclusion criteria for in-depth review.

Analysis Strategy

The three articles were analyzed based on the following factors.

1. Publication year between 2020 and 2025
2. Ranked in Scopus (Q1, Q2, and Q3)
3. Research objectives

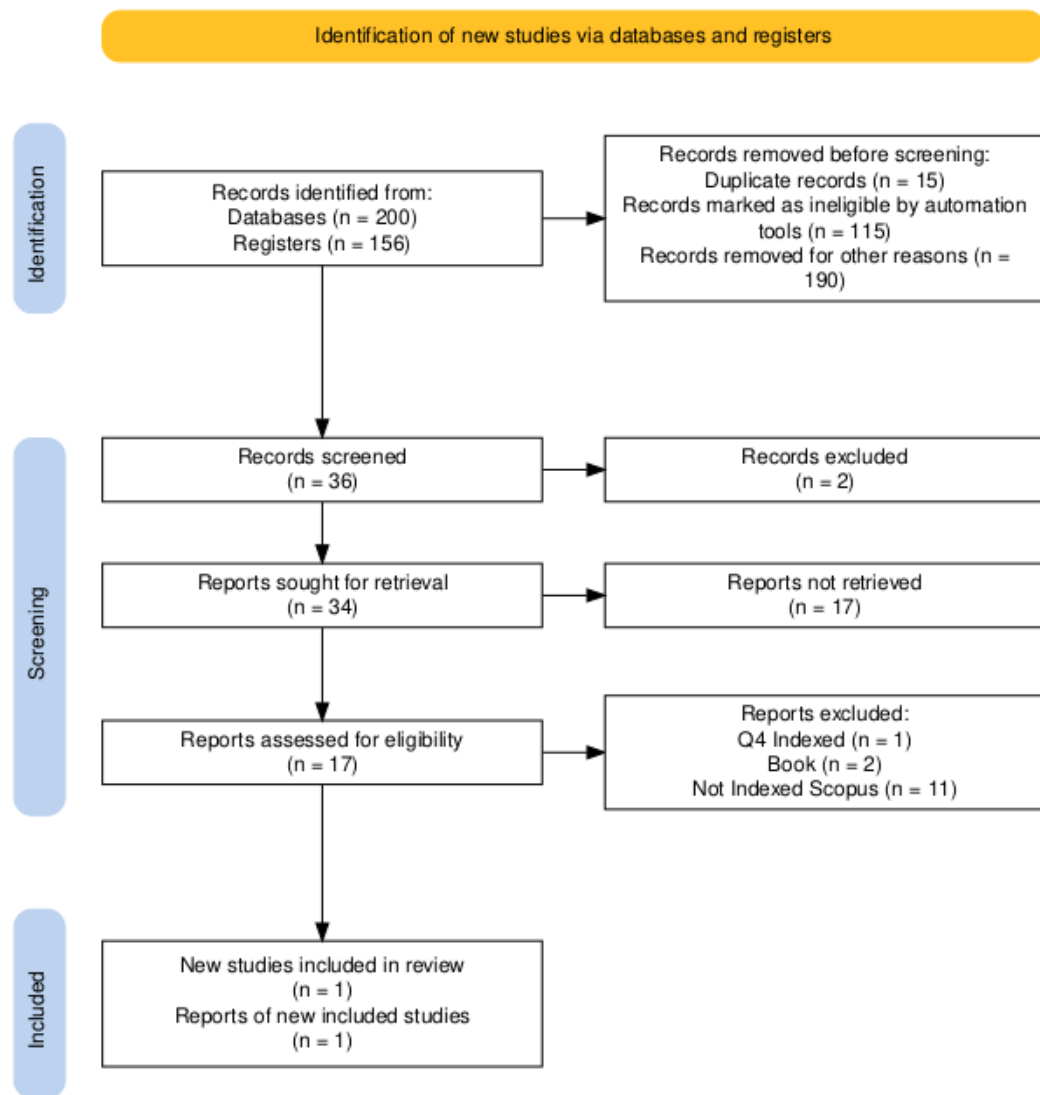


Figure 1. PRISMA Flow Chart (Haddaway et al., 2022)

Data Coding and Analysis

There were two steps in conducting the research. The first one was creating a table to classify the articles obtained for analysis. Then, the second step was synthesizing data based on the three factors contained in the analysis strategy.

Findings and Discussion

This review presents the synthesized results of research on the use of artificial intelligence in mathematics education, which covers the use of artificial intelligence in teaching and learning activities and the use of artificial intelligence as a learning medium. Research conducted by Opesemowo et al. (2024) entitled “Artificial intelligence in mathematics education: The good, the bad, and the ugly” states that integration of artificial intelligence in mathematics education offers promising advances as well as potential obstacles.

Artificial Intelligence's Potential for Learning Mathematics

The use of artificial intelligence has the potential to enhance the experience of learning mathematics, namely:

For students

Artificial intelligence-assisted learning can help students, among other things, to identify individual needs, learning styles, and performance through the analysis of artificial intelligence algorithms. Not only that, but AI technologies, such as virtual simulations and gamification, can create an engaging learning environment. Thus, these tools can encourage students to be more active and practice problem-solving and critical thinking skills, making mathematics feel easier and more enjoyable. There are Augmented Reality applications that can make mathematical concepts more real by displaying digital information in the real world. Recent findings show that increased access to mathematical content through digital connectivity is now part of broader teaching practices, with teachers' digital practices influencing how students experience mathematics learning (Attard & Holmes, 2020). The context of how AI can help identify individual student needs, particularly in relation to cognitive and language abilities, also has a strong empirical foundation. For example, research on the role of language in mathematical problem-solving shows that reading ability and language resources are highly relevant to success in solving word problems and mathematics learning in general, implying that AI systems assessing student responses need to consider language load and include appropriate linguistic support (Reinhold et al., 2020).

For teachers

In addition to its benefits in developing students' abilities, artificial intelligence also has a positive impact on teachers. Artificial intelligence can automatically correct math assignments and exams, saving teachers time so they can focus on other aspects of teaching. This assistance makes teachers faster, more efficient, and more accurate in their assessments. Furthermore, artificial intelligence can assist mathematics teachers by providing personalized training, modules, and learning resources tailored to their needs, based on performance analysis and areas that need improvement. Personalized learning modules can be developed by AI with reference to evidence of effective practices in mathematics professional development, such as developing mathematical thinking skills through multiple representation tasks and diverse task interactions. One of the main pillars of AI in teacher professional development is its ability to build teacher learning profiles based on current knowledge and beliefs, so that training can be personalized to address their specific needs. Thus, AI that analyses teachers' perceptions and realities of practice can train pathways that enhance content competence while mitigating attitudinal barriers to practice change.

Challenges and Limitations

While artificial intelligence may have a significant impact on mathematics education, it has several challenges and limitations, these are:

For students

The use of artificial intelligence has several drawbacks, including a lack of creativity and problem-solving skills. Although AI is increasingly deployed as a pedagogical aid, a considerable body of research in mathematics education emphasizes that meaningful creativity and robust problem-solving emerge from carefully designed learning environments, contexts, representations, and curricular structures that support inquiry, ambiguity, and authentic practice, and an inability to explain thought processes. An excessive focus on computational skills, a lack of emotional intelligence, a loss of critical thinking skills, and a dependence on artificial intelligence for problem-solving also cause limitations. The main emphasis is that human problem-solving behavior is influenced by a spectrum of cognitive, affective, and social agency abilities. Reliance on AI for computational tasks can reduce opportunities for developing these capabilities (Reinhold et al., 2020). Creative power, agency, and collaboration in mathematical problem-solving are also important focuses. The dynamics of agency among learners when solving problems, where one agent may lead the conversation with mathematically meaningful arguments, while other agents tend to listen without developing further mathematical arguments, so that collaboration often does not reach a level of mutually challenging discussion or produce new understanding (Hansen, 2022). Reliance on AI to automatically perform representation and representation conversation processes can reduce opportunities for learners to actively construct their own mental representations, which in turn can affect the improvement of critical thinking skills and the formation of adaptive problem-solving strategies. Therefore, AI for mathematics learning should be designed to facilitate, rather than replace, the representational exploration and thinking tools that students need to develop modelling and quantitative reasoning skills.

For Teacher

In teaching, teachers must follow the applicable curriculum. When using artificial intelligence, teachers only follow learning paths that have been determined by data and algorithms. If there are changes to the curriculum, the content presented will not be in line with the latest requirements. Modern mathematics learning places teachers as the main link between the applicable curriculum and classroom learning practices. This role becomes more complex when artificial intelligence (AI)-based devices or data-based learning technologies are involved, because the learning paths presented are often regulated by data and algorithms working behind the scenes (Attard & Holmes, 2020). The curriculum, as a normative framework governed by education policy, is revised periodically to reflect expected competency requirements and relevant scientific trends. When curriculum changes occur, the content AI presented risks of being out of sync if the content update mechanism is not directly integrated with the curriculum update process. Therefore, the literature suggests that although AI and technology can offer more dynamic solutions, the role of teachers remains central in interpreting, aligning, and assessing the suitability of materials to new national and local standards. In practical terms, a framework is needed that integrates AI with curriculum through evidence-based learning design, continuous professional learning, and cross-stakeholder collaboration in schools.

Another study discussing the use of artificial intelligence in mathematics, entitled ChatGPT: A revolutionary tool for teachers and learning mathematics

(Wardat et al., 2023), found that the use of ChatGPT can improve mathematical ability. Not only that, but this message-based application also provides users with basic knowledge about mathematics and various other topics. This is confirmed in research that highlights that the use of technology can expand opportunities for learning mathematics through different access channels and through dynamic concept visualization, as well as providing more flexible feedback and communication between teachers and students (Attard & Holmes, 2020). These findings are consistent with other studies that emphasize the role of engagement, motivation, and learning context as key mediators between technology and mathematical achievement (Skilling et al., 2020). Thus, it provides a theoretical basis for the assumption that AI conversation tools can replicate the benefits of technology-based learning, provided that the instructional design and implementation context consider the principles of effective learning (Attard & Holmes, 2020; Skilling et al., 2020). Furthermore, this literature emphasizes that planned learning practices—including the design of deliberate practice, exercise variation, and carefully managed cognitive load—can promote more enduring mathematical knowledge formation and more effective problem-solving abilities. In solving mathematical problems, ChatGPT has a capable capacity with the use of artificial intelligence algorithms and machine learning, so that it can present solution steps to its users. The results of its answers are represented in text or visual formats, making it easy for users to understand the problems and their solutions. One of these pillars is the use of spatial and graphical representations as reasoning aids, given that spatial visualization skills may contribute significantly to problem-solving that utilizes geometric shapes or visual patterns. At the same time, the ability to translate real-world situations into quantitative models—which involves interpreting quantities, relationships between variables, and representations through various forms—is shown to be strongly linked to modelling capacity and quantitative understanding in students and prospective educators. Therefore, interaction designs that combine the elaboration of representations (text, diagrams, tables) with conceptual modelling steps can enhance the quality of AI assistance in solving mathematical problems (Hansen, 2022).

Despite its advantages, ChatGPT also has limitations. One of them is the potential for bias caused by users. In the context of mathematics learning and reasoning practices, educational literature shows that bias can arise when only one representation is used, or when language and argument structure are inadequate to reveal the actual cause and effect. Furthermore, studies on how mathematical activities are learned and interpreted through the modelling process show how the phases of modelling and the choice of objects and semiotic signs can limit or shape the user's interpretation. Efforts to understand the interaction between users and models can also be explained through studies that emphasize the importance of how variation, symbolism, and argumentative proof guide students' understanding and how bias can arise if the context is not presented comprehensively. Therefore, this study attempts to integrate these findings to explain how user-generated bias can occur in the dynamics of interaction with ChatGPT, and how educational practices based on dual representation, argument structure, and modelling approaches can inform strategies to mitigate such bias. In general, this framework positions bias as a phenomenon that arises at the intersection of context, language, representation, and users' epistemic practices, rather than simply an attribute of the model. With

this foundation, we can discuss how users can inadvertently shape model outputs through how they structure requests, the language used, and the conceptual frameworks brought to life in dialogue. The continuation of this argument stems from the idea that representation, argumentation, and modelling are social practices that shape understanding, so bias needs to be analyzed through these lenses to formulate more appropriate intervention strategies. This also provides space to develop training practices and prompt designs that encourage users to activate various representations and construct more structured arguments.

In summary, this discussion links potential user bias to three key pillars in the education literature: multiple representations, argumentation frameworks, and semiotic modelling dynamics, which can then be used as a basis for designing interfaces that are more resilient to bias. Such a review is important because if bias is not recognized or properly unpacked, the resulting responses may reinforce user misinterpretations rather than reflecting correct knowledge. Thus, the purpose of this analysis is to formulate how the strengths and limitations of representation and the structure of argumentation and modelling play a role in the formation of user bias in the context of interactions with ChatGPT, and to offer strategies based on the educational literature to reduce this bias.

Conclusion

Based on the results of the literature review, it was found that the benefits of using artificial intelligence can help students understand difficult mathematical concepts by presenting answers in text and visual form. In addition, artificial intelligence can also help teachers improve their knowledge through personalized training. Despite all the advantages of artificial intelligence, this man-made application also has several limitations. One of them is the potential for bias caused by its users. This cannot reveal the actual cause and effect. Therefore, users need to consider whether the answers generated by this application are correct or still need improvement.

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DEVELOPING INTERACTIVE SNAKES AND LADDERS MEDIA TO ENHANCE STUDENTS' UNDERSTANDING OF REPRODUCTIVE SYSTEM CONCEPTS

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Received: 31 October 2025; Accepted: 1 December 2025

Abstract

This research aims to develop an interactive Snakes and Ladders learning medium that can improve students' understanding of human reproductive system material. Using the Design Thinking approach, which consists of five stages: Empathize, Define, Ideate, Prototype, and Test. The research examines students' needs and challenges in understanding biology material, particularly the reproductive system, which is often considered complex and abstract. Based on this needs analysis, a solution was developed in the form of an educational board-game-based learning tool that integrates educational elements with gameplay. Initial testing results involving 10 students, obtained qualitatively through feedback and opinions from testing subjects, indicate that this tool effectively enhances student engagement, learning motivation, and material comprehension. The qualitative approach involved collecting data through interviews, allowing researchers to gather in-depth insights into the tool's effectiveness. Users provided positive feedback on this media due to its fun and interactive nature, as well as its alignment with the principles of the Merdeka Curriculum, which emphasizes experiential learning and active student participation. In addition, this media has the potential to be adapted and used in other subjects. Therefore, this interactive Snakes and Ladders media is considered suitable for use as an effective and meaningful alternative to support learning.

Keywords: design thinking, human reproductive system, interactive snakes and ladders, learning media

Introduction

Educational reform in Indonesia, as mandated by the National Education System Law No. 20 of 2003, requires learning practices that remain responsive to global developments while enabling students to cultivate their full potential (Marita, 2023). In the 21st century, learners are expected to master a broad set of competencies, including creative thinking, communication, technological literacy, and adaptability (Griffin & Care, 2015). These competencies are further emphasized by Suryanto (2021), Maknuunah et al. (2023), and Risdiyanto et al.



(2018), who highlight creativity, innovation, and flexibility as essential for success in contemporary learning environments. Although critical thinking remains one of the central objectives of education (Suryanti et al., 2018; Kalelioğlu et al., 2014; Robbins, 2011), the present study focuses more specifically on challenges related to students' conceptual understanding in Biology, particularly in the topic of the human reproductive system.

The human reproductive system is widely recognized as one of the most complex topics in Biology due to its abstract concepts, numerous scientific terms, and sensitive nature. These characteristics often limit student engagement and contribute to misconceptions, as learners may find the material difficult to visualize and relate to real-life contexts. In Biology learning, complex materials such as the human reproductive system require visualization to make the subject matter more accessible. Media that integrate text, images, and interactivity are essential to bridge the gap between abstract content and meaningful comprehension. However, in many classroom practices, instruction still relies predominantly on conventional explanations and static diagrams, offering limited visual support and insufficient opportunities for active engagement. Consequently, students often fail to form accurate mental representations of reproductive structures and processes, resulting in a fragmented or superficial understanding. This persistent gap between the cognitive demands of the material and the limited availability of engaging, pedagogically sound learning tools represents the core problem addressed in this study.

To resolve this issue, the theoretical foundation provided by Mayer's (2009) cognitive theory of multimedia learning is particularly relevant. The theory posits that learning becomes more effective when information is presented through coordinated visual and verbal channels, allowing students to optimize their working memory and reduce extraneous cognitive load. When multimedia materials are designed coherently, students are better able to select, organize, and integrate new information into meaningful mental models. Studies in biology education support this principle, demonstrating that interactive and visually rich media can transform abstract scientific concepts into more comprehensible and memorable learning experiences (Srikandhi et al., 2024). Thus, multimedia-based instructional tools hold strong potential for addressing conceptual difficulties in reproductive system learning.

One promising form of multimedia intervention is game-based learning. Games can increase motivation, strengthen engagement, and promote conceptual processing by embedding instructional goals within interactive activities. Modified versions of the Snakes and Ladders game, in particular, allow for the integration of content explanations and question prompts within a familiar and enjoyable format. Apriani et al. (2025) report that such game-based media can effectively improve students' conceptual understanding and learning motivation in Biology. These characteristics align closely with the principles of the *Merdeka* Curriculum, which emphasizes student-centered learning, meaningful exploration, and the integration of approaches such as Project-Based Learning to foster autonomy and active participation.

Building upon these foundations, this study aims to develop and evaluate an interactive Snakes and Ladders game designed specifically to support students' understanding of the human reproductive system. The media is intended to reduce

cognitive load, provide meaningful visualization, and create an engaging learning environment consistent with contemporary educational expectations. Ultimately, this research seeks to contribute to the advancement of instructional media that are both effective and aligned with the pedagogical principles of the Merdeka Curriculum.

Educational Media Development

The use of educational media is a fundamental component in achieving learning effectiveness. Media can transform abstract scientific concepts into concrete and visual experiences that facilitate students' comprehension. According to Srikanthi et al. (2024), the integration of visual and interactive media in classroom learning contributes significantly to students' motivation and knowledge retention. By providing multisensory stimulation, learning media not only improve understanding but also create enjoyable learning environments.

In Biology learning, complex materials such as the human reproductive system require visualization to make the subject matter more accessible. Media that integrate text, images, and interactivity can bridge the gap between abstract content and real-life understanding. The development of interactive media must also align with pedagogical goals, curriculum standards, and the technological readiness of both students and teachers. The inclusion of game elements within educational media enhances the element of engagement, which is essential for promoting active learning and curiosity.

Game-Based Learning Framework

Game-based learning is a pedagogical approach that incorporates game principles such as goals, rules, challenges, and feedback into educational contexts. It aims to engage students in learning through meaningful play experiences (Gee, 2018). Games provide opportunities for learners to explore, make decisions, and experience the consequences of their actions in a safe and structured environment. This dynamic process enhances motivation and reinforces knowledge through repetition and problem-solving.

The snakes and ladders game, traditionally a recreational activity, can be adapted into an educational tool by embedding subject-related content such as question cards and contextual challenges. When applied in the Biology classroom, each ladder can symbolize progress achieved through correct understanding, while snakes represent conceptual errors or misconceptions. This approach not only reinforces content mastery but also cultivates critical thinking and perseverance.

As emphasized by Apriani et al. (2025), interactive snakes and ladders media can enhance students' learning motivation and conceptual comprehension by transforming passive learning into an engaging and competitive experience. Furthermore, this framework aligns with the Merdeka Curriculum's philosophy of creating learner autonomy and joy in education. By implementing the game-based learning approach within this curriculum, teachers can create an inclusive and interactive classroom environment that promotes collaboration, critical thinking, and self-reflection among students.

The Merdeka Curriculum and Student-Centered Learning

Education in Indonesia continues to experience curricular transformation to respond to technological, social, and global demands. In general, a curriculum is defined as a set of plans and arrangements regarding objectives, content, learning materials, and teaching methods that guide the implementation of classroom instruction to achieve educational goals (Fatimah, 2021). As these demands evolve, the development of high-quality human resources becomes increasingly necessary, especially considering challenges such as rapid technological advancement, the need for curriculum adaptation, and resistance to change within educational systems (Mustopa et al., 2021).

Within this broader context, Indonesia introduced the Merdeka Curriculum as part of its ongoing educational reform. The Pocket Book of Questions and Answers for the Merdeka Curriculum describes it as a curriculum that offers diverse intra-curricular learning opportunities, enabling students to have sufficient time to deepen conceptual understanding and strengthen their competencies (Heppy, 2022). The curriculum represents a shift toward competency-based education that prioritizes student-centered learning, experiential engagement, and the cultivation of learner autonomy.

Aligned with these principles, the Merdeka Curriculum explicitly promotes Project-Based Learning (PjBL) as a core instructional approach. PjBL positions students as active constructors of knowledge through authentic, meaningful, and inquiry-driven activities. Consequently, learning media within this framework are not merely tools for delivering information but must function as scaffolds that support student exploration, encourage independence, and accommodate varied learning pathways.

The curriculum's emphasis on "learning independence" and "joyful learning" also aligns naturally with game-based pedagogical approaches. Games inherently promote autonomy, self-paced learning, decision-making, and intrinsic motivation, key characteristics of the student-centered vision embedded in the Merdeka Curriculum. However, the integration of game-based media must be carefully designed to ensure alignment with learning objectives, appropriate assessment strategies, and a balanced interplay between instructional structure and student flexibility.

Design Thinking as a Development Framework

The development of educational media requires systematic methodologies that ensure both pedagogical effectiveness and user-centered design. Design Thinking, a human-centered innovation approach consisting of five iterative stages: Empathize, Define, Ideate, Prototype, and Test, provides a robust framework for creating solutions that genuinely address user needs (Brown, 2008; IDEO, 2015). Unlike traditional linear development models, Design Thinking emphasizes deep understanding of user experiences, rapid prototyping, and continuous refinement based on authentic feedback.

In educational contexts, Design Thinking enables developers to move beyond assumptions about student needs and preferences, instead grounding design decisions in empirical observation and iterative testing. In the context of education, design thinking has been proven to be capable of improving students' critical thinking skills, creativity, and problem-solving abilities (Ghufrooni, 2023). The

Empathize stage involves understanding students' learning challenges, preferences, and contexts through observations and interviews. The Define stage synthesizes these insights into clear problem statements. Ideation generates diverse potential solutions, while Prototyping creates tangible manifestations for testing. Finally, the Testing stage gathers user feedback to inform further refinement.

This approach is particularly appropriate for developing game-based learning media, as it ensures that educational objectives remain balanced with engagement and usability considerations. By centering students' voices throughout the development process, Design Thinking aligns naturally with the Merdeka Curriculum's philosophy of student-centered education. In Indonesia, the application of design thinking in education still faces significant challenges. This aligns with research (Satria & Muntaha, 2022) indicating that teachers' lack of understanding of this method and limited resources are the main obstacles to its implementation. In fact, innovations like design thinking are very important for creating project-based learning that is relevant to students' needs and modern technological developments.

Research Gap and Objectives

Despite growing interest in game-based learning and the proliferation of educational board games, significant gaps remain in the literature. First, existing educational adaptations of traditional games often lack rigorous theoretical grounding in instructional design principles and learning theories. Second, few studies have systematically applied Design Thinking methodologies to the development of educational games, particularly in Biology education (Freiberg & Callegaro, 2025). Third, while the Merdeka Curriculum emphasizes student-centered, experiential learning, limited research has explored how game-based media can be systematically designed to support this framework's specific pedagogical goals.

Furthermore, the human reproductive system, despite its curricular importance, remains underserved by innovative educational media, particularly in the Indonesian context, where cultural sensitivities require careful pedagogical consideration. Existing learning materials tend toward either overly clinical presentations that fail to engage students or oversimplified approaches that do not adequately address conceptual complexity.

Therefore, this study aims to develop and evaluate an interactive Snakes and Ladders learning medium for teaching the human reproductive system, utilizing Design Thinking as the development framework. Specifically, the research addresses the following objectives: (1) to identify students' learning needs and challenges related to reproductive system material through systematic user research; (2) to design and prototype an interactive Snakes and Ladders game that integrates educational content with engaging gameplay mechanics. By addressing these objectives, this study contributes both a practical educational tool and methodological insights into user-centered development of game-based learning media within contemporary Indonesian educational contexts.

Method

This study employed the Design Thinking approach as the primary framework for developing an interactive learning medium. Design Thinking

focuses on a deep understanding of user needs, in this case, students, and on generating innovative, practical, and human-centered solutions to educational challenges. This approach consists of five main stages: Empathize, Define, Ideate, Prototype, and Test. Each stage was implemented sequentially to ensure that the product design met students' actual needs and learning characteristics (Fujiawati et al., 2023)

Empathize Stage

The first stage, Empathize, focused on understanding students' learning experiences, challenges, and preferences related to the biology material, particularly the human reproductive system (Chen et al., 2023). Data were collected through direct interviews with six students from SMA Negeri 6 Yogyakarta. The participants were selected purposively based on their academic performance and learning motivation, representing both ends of the achievement spectrum. Students from classes XI F1–F3, categorized as having relatively lower academic achievement and learning motivation, were positioned on the left extreme, while students from classes XI F6–F8, who demonstrated higher academic performance and motivation, represented the right extreme. This selection ensured diversity of perspectives in identifying learning needs. The goal of this stage was to obtain an authentic understanding of students' viewpoints regarding the learning process, including their difficulties, expectations, and preferred learning media. Insights from this stage revealed that students desired media that were enjoyable, easy to understand, and interactive, capable of transforming abstract concepts into engaging learning experiences.

Define Stage

In the Define stage, the researchers synthesized information gathered during the Empathize phase to determine the core problem. The findings showed that many students perceived biology materials, particularly the reproductive system, as difficult to understand due to their abstract presentation and lack of engaging instructional approaches. Therefore, the main problem statement formulated was: *"Students find biology lessons challenging because they are abstract, less interactive, and insufficiently supported by media that stimulate learning motivation."* This problem definition became the foundation for designing a creative learning solution through media development.

Ideate Stage

The Ideate stage involved generating and refining creative ideas to design a potential solution addressing the defined problem. The researchers conducted brainstorming sessions and collaborative discussions to produce innovative concepts that could improve students' understanding of the reproductive system (Firdaus et al., 2024).

The following steps were undertaken:

1. Reviewing student interviews and observations: Researchers revisited the data collected from SMA Negeri 6 Yogyakarta, focusing on students' difficulties, learning styles, and dissatisfaction with conventional classroom methods.

2. Brainstorming ideas: Group discussions were conducted to gather as many ideas as possible without immediate judgment. All ideas were recorded and categorized based on potential effectiveness and feasibility.
3. Selecting the most promising idea: After evaluating aspects such as interactivity, engagement, ease of use, and conceptual reinforcement, the team decided to develop an interactive Snakes and Ladders educational game.
4. Formulating the design concept: The game was conceptualized to present the human reproductive system through fun yet educational gameplay.
5. Developing the gameplay scenario: A detailed structure of the game was designed, including group formation, question mechanics, scoring, penalties, and winner determination. The questions were categorized by difficulty levels and designed to encourage collaboration among players.

Prototype Stage

The fourth stage, Prototype, in the prototype phase of developing interactive snakes and ladders learning media, involves a series of structured activities aimed at realizing the initial idea into a tangible form that can be tested by users (Syawaluddin et al., 2020). The steps taken are as follows:

1. The first step is to determine the purpose of creating the prototype.
2. Determining the form and level of detail of the prototype. The prototype developed in the initial stage is low-fidelity, consisting of manual sketches and preliminary designs of the snake and ladder media in printed form.
3. Developing the initial prototype of the media and then creating a preliminary prototype based on the ideas and design concepts agreed upon in the previous stage.
4. The prototype that has been created is tested directly on a small group in the class as a first step.
5. Feedback is gathered, and revisions are made after the initial testing.
6. The prototype is prepared for further testing. The revised prototype is then prepared for use in further testing (the Testing phase).

Test Stage

The fifth stage of testing is the final stage of the design thinking process, which aims to test the effectiveness and functionality of the interactive snake and ladder media that has been developed (Ernawati et al., 2025). The steps taken in this phase are as follows:

1. The first step is to design a systematic testing process.
2. The test subjects are biology students at Sanata Dharma University, who are the target users of the media. Although the needs analysis involved high school students, the prototype was first tested with biology education students at Sanata Dharma University as an initial usability test. This step ensured that the accuracy of the content and game mechanics had been validated by individuals with sufficient background knowledge prior to wider implementation at the school level.
3. The interactive snake and ladder media is tested directly in a learning context.

4. Data collection and respondent feedback are gathered by answering evaluation questions so that researchers can obtain feedback.
5. The results and revised data obtained from observations, tests, and interviews are analyzed to evaluate the strengths and weaknesses of the media.

Testing was conducted by trialing the Snake and Ladder media with students. Student feedback was also collected to determine the extent to which the media met expectations, as well as the parts that needed improvement. The results of this stage were used to revise and refine the media before it was implemented more widely.

Findings and Discussion

This product was developed using a design thinking approach, which involves several stages: Empathize, Define the problem, Ideate, Prototype, and Testing (Shé et al., 2021).

The Empathize stage was carried out by interviewing six male and female students attending SMAN 6 Yogyakarta. This school was chosen because it had previously established a good cooperative relationship in the School Introduction Program: Learning Management (PLP-PP). In addition, the selection of these six students was based on a sample development strategy, where the sample was divided into two large groups: the extreme left and the extreme right.

The extreme left represented academically intelligent students, and the extreme right represented academically less intelligent students. This was also supported by the results of the interviews that had been conducted. The left extreme (classes XI F1-XI F3) felt that Biology lessons were quite enjoyable and easy to follow with the concepts taught, the assignments given, and good communication with the teacher, while the right extreme (XI F6-XI F8) tended to have difficulty understanding the concepts and content of the lessons given. This was due to the difficulty of memorizing names in Latin, the amount of memorization required, teaching methods that are considered irrelevant and ineffective, and assignments that are considered burdensome for students rather than helping them to deepen their understanding of the material taught. School observations also reveal that the school conducts a selection process to divide students who will advance to grade XI based on their IQ scores.

Define the Problem stage: after conducting interviews, the next step is to formulate problems based on the findings from the empathy stage. After observing and interacting directly with students, the researcher began to identify and compile several problems that arose in the biology learning process. Based on the data collected, it can be concluded that many students have difficulty understanding the material because it is presented in a theoretical manner and does not involve active student participation. In addition, the learning media used tended to be monotonous, so students quickly became bored and less motivated to explore the material in depth.

To clarify the direction of development, these problems were classified and narrowed down to one main formulation. The process of formulating this was important so that the solutions developed were truly on target and in line with the needs of the end users (Murray et al., 2019). The main issue that is the focus of this stage is clearly defined: How can we develop interactive learning media so that 11th-grade students at SMA Negeri 6 Yogyakarta can better understand biology material and improve their academic performance? With this formulation, the

development of media is directed at increasing the effectiveness of learning and student achievement.

Ideate Stage After the problem formulation is agreed upon, the next stage focuses on searching for and developing various solution ideas. In this phase, creative exploration is carried out by considering various alternative learning media that have the potential to meet the needs and characteristics of students. Various concepts emerged from the discussions, ranging from the creation of board-based game media, such as educational Snakes and Ladders, the creation of mini ecosystems that can be used as direct observation media, the use of interactive digital applications such as Quizizz and Kahoot for class quizzes, to the collection of plant specimens in the form of herbaria as project-based learning media. From these many alternatives, various factors were considered, such as student engagement, resource availability, ease of implementation in the classroom, and relevance to learning objectives. Finally, it was decided that interactive snakes and ladders would be the primary medium to be developed further. This medium not only has the potential to attract students' interest through a game-based approach, but also contains structured educational elements through questions tailored to basic competencies. Thus, the learning process is expected to be more participatory, enjoyable, and meaningful.

Prototype Stage: The designed learning media were presented along with the rules and mechanisms for playing the Snakes and Ladders game. In addition, the learning media was played by representatives from each group. The initial design of the media was realized in the form of a simple prototype containing the main components, such as a game board, question cards, pawns, and dice. These components were arranged based on the concept of human reproduction learning and adapted to the predetermined learning objectives. In the initial development process, the prototype was designed with a simple (low-fidelity) approach so that it could be quickly adapted and improved if any shortcomings were found. The media design included visual elements in the form of illustrative images of the reproductive system, as well as questions with varying levels of difficulty, ranging from easy, medium, to difficult, and matching questions. This interactive Snakes and Ladders game uses question cards that are directly related to the learning objectives of the human reproductive system topic. Each card contains conceptual or analytical questions designed to stimulate student understanding and discussion. For example, some of the questions asked are: "How do FSH and LH interact in regulating the menstrual cycle?" "Explain the main differences between spermatogenesis and oogenesis in terms of their outcomes," or "What would happen if progesterone were not produced after ovulation?" "How do the structure and function of the testes support sperm production?"



Figure 1. Initial Design of the Snakes and Ladders Game



Figure 2. Example of Question Categories

After the prototype was completed, a simulation of its use in the classroom was conducted with representatives from each group. At this stage, the prototype was not only presented but also tested directly by demonstrating the flow of the game, including its rules and interaction mechanisms. Participants were asked to try playing the media directly, while the developers observed the responses and dynamics during the activity. Through testing the learning media, which were still

in prototype form, several suggestions and questions were raised for evaluation, both in terms of the physical aspects of the snake and ladder learning media and the applicable mechanisms and rules.

Several individuals provided suggestions and raised questions regarding the rules of this learning medium. They questioned whether each square should contain a question, and what would happen if a player answered incorrectly, whether the player should move back two steps or remain on the same square until the next turn. They also asked whether a pawn landing on a ladder could immediately move up, or whether the player needed to answer a question first. If a question was answered correctly, the pawn could climb the ladder; if answered incorrectly, it would stay in place. In addition, there were constructive suggestions such as improving the material used for the dice so that it is more durable when played, the pawns used are too small, there are no keywords in each question given, and the rules in the point system need to be clarified.

The testing stage involved testing the interactive Snakes and Ladders media to determine its contribution to increasing engagement and understanding of the human reproductive system material. To ensure that this media was suitable for the target users, the testing involved students from the Biology Education study program at Sanata Dharma University. Participants were selected purposively to represent various levels of academic ability, so that the data obtained reflected the diversity of responses to the developed media.

The testing was conducted in the form of a learning simulation, where students played the Snakes and Ladders media in small groups. During the session, researchers directly observed group dynamics, decision-making processes, understanding of the questions provided, and interactions between group members. In this activity, researchers also noted moments when participants appeared to have difficulties, were confused, or were enthusiastic. After the game was over, participants were asked to respond to several evaluative questions related to their experience while using the media. The feedback provided was used as a source of information to assess the effectiveness of the media and was then analyzed to identify areas for improvement.

Conclusion

This study successfully developed an innovative learning medium in the form of an interactive snakes and ladders game as a learning aid for teaching human reproductive systems. The media development process was carried out using the Design Thinking approach, which consists of five main stages: Empathize, Define, Ideate, Prototype, and Test. This media proved to be effective in increasing student engagement, motivation, and understanding of material that is often considered difficult and abstract.

The results of the study show that the interactive Snakes and Ladders medium is able to harmoniously combine educational elements with games, thereby creating a more interesting and enjoyable learning experience. The use of this media helps students understand the material more deeply and contextually, in accordance with the principles of the Merdeka Curriculum, which emphasizes experience-based learning and active student participation.

In addition, preliminary testing of the media shows that it can overcome the challenges of conventional learning, which lacks interactivity. With the integration

of learning through games, students become more motivated to learn and find it easier to understand the concepts being taught. Therefore, this interactive snake and ladder media is considered feasible to be implemented as an innovative and meaningful alternative to support Biology learning, especially in the material on the human reproductive system. Based on the findings, this media can also be applied to other materials or other learning contexts.

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INTEGRATION OF ECOLOGICAL LOCAL WISDOM IN GRADE VII JUNIOR HIGH SCHOOL INDONESIAN LANGUAGE COURSEBOOKS IN CENTRAL JAVA

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Received: 24 November 2025; Accepted: 7 December 2025

Abstract

This study analyses the representation of ecological local wisdom in three seventh-grade Indonesian language coursebooks used in junior high schools across Central Java, Indonesia. Adopting a qualitative design with a content analysis approach, the research examines textual and visual elements—words, phrases, sentences, paragraphs, and illustrations—within the coursebooks. Data validity was ensured through triangulation using multiple ecological and cultural perspectives. The study's novelty lies in its focus on the integration of ecological local wisdom within Indonesian language materials, a topic that remains underexplored in the Central Java context. The findings indicate that, although elements of local wisdom are present, their ecological dimensions are not explicitly articulated or systematically integrated into the learning materials. Moreover, the identified local wisdoms originate from various provinces—such as Riau, Yogyakarta, Aceh, West Java, East Nusa Tenggara, and Papua—rather than from Central Java itself. This geographical mismatch poses challenges for contextual learning among teachers and students in the region. The study concludes that developing regionally grounded and ecologically responsive Indonesian language coursebooks is essential to promote contextual literacy and strengthen students' ecological awareness.

Keywords: coursebooks, Central Java, ecological literacy, Indonesian language learning, local wisdom

Introduction

The history of humankind demonstrates that fears of an impending global energy shortage have proven unfounded. For instance, concerns over the depletion of fossil fuels such as petroleum have been mitigated through human innovation in alternative energy sources, including electricity and steam power, which replaced coal-based energy. This evolution indicates that the true existential threat to humanity lies not in an energy crisis but in environmental degradation. The planet currently faces severe ecological damage driven by climate change, global warming, non-degradable plastic waste, deforestation, and other destructive human activities (Harari, 2020).

According to the WorldRiskReport (Frege et al., 2023), Indonesia ranks second among countries with the highest disaster risk, following the Philippines (WRI 46.91), with Indonesia (WRI 41.13) and India (WRI 40.96) completing the



top three. The country's forests are also under alarming pressure, with deforestation between 2017 and 2021 averaging 2.54 million hectares per year—equivalent to six football fields per minute—placing Indonesia on the brink of a climate crisis. Forest degradation occurs across all regions, including Java, which loses approximately 22,000 hectares annually (Purba et al., 2018). Water ecosystems face similar threats as watershed areas are converted into residential zones or exploited by corporations, resulting in floods, sedimentation, and widespread droughts (KOMPAS, 2023).

These issues largely stem from human indifference toward the environment. As Ramlan et al., (2023) emphasize, ecological literacy must be instilled in younger generations, who will inherit an increasingly degraded planet. Ecological literacy involves understanding the reciprocal relationship between humans and nature, enabling individuals to interpret environmental systems and take appropriate actions to sustain or restore them (Roth, 1992). It encompasses four dimensions—knowledge, skills, affect, and behavior—with the ultimate goal of developing environmentally responsible citizens.

Previous studies highlight that integrating local wisdom into education significantly enhances students' conceptual knowledge and environmental literacy (Lubis et al., 2022). Wibawa and Awaliah (2023) argue that preserving indigenous knowledge related to biodiversity conservation requires community-based resource management integrated into local curricula. At the junior high school level, Suwandi et al., (2019) recommend embedding all components of environmental literacy within textbooks. Moreover, Toharudin et al., (2021) note that local wisdom-based learning can be effectively combined with technological advancements.

Building upon these findings, strengthening ecological literacy among junior high school students in Central Java can be achieved by utilizing local ecological wisdom rooted in the province's cultural practices. However, Suwandi et al., (2024) report that existing Indonesian language textbooks still lack sufficient emphasis on ecosystem preservation. Similarly, Suwandi et al. (2016) found that ecological literacy content in Indonesian language materials remains predominantly cognitive, neglecting affective, behavioral, and applied aspects.

Indonesian language learning at the junior high level not only develops linguistic competence but also serves as a medium for cultivating cultural and local values. Among these is ecological wisdom—understood as local knowledge, attitudes, and practices that maintain environmental balance. Integrating such wisdom into textbooks is crucial amid today's environmental crises, climate change, and ecosystem degradation. As the primary learning source, textbooks play a strategic role in fostering ecological awareness through narratives, folklore, descriptive texts, and visual materials that communicate messages of environmental stewardship.

Central Java, with its rich ecological traditions such as *sedekah bumi* (earth offerings), *sedekah laut* (sea offerings), and nature-related myths and legends, holds significant potential for integrating local ecological wisdom into Indonesian language learning. These traditions embody ecological values that can strengthen students' environmental literacy and reinforce cultural identity grounded in local wisdom. Nevertheless, the extent to which such integration exists in seventh-grade Indonesian language textbooks used in Central Java remains underexplored. Therefore, this study aims to analyze the integration of ecological local wisdom

within seventh-grade Indonesian language coursebooks used in junior high schools across Central Java.

Ecological Literacy in Education

Ecological literacy is essential in addressing current global environmental challenges, such as climate change, ecosystem degradation, and loss of biodiversity. Orr (1992) asserts that ecological literacy is a crucial foundation for education that supports sustainability. Ecological literacy helps individuals understand how their actions impact the planet and encourages them to behave responsibly towards the environment.

Goleman et al. (2012) emphasize the importance of ecological literacy in developing a generation capable of facing environmental crises. They identified that ecological literacy must be an integral part of the education system, from primary to higher education. In this case, ecological literacy education should not only focus on conveying scientific facts, but also on developing critical awareness and skills to take appropriate action in facing environmental problems. The implementation of ecological literacy in education requires a holistic and interdisciplinary approach. Ecological literacy education must integrate scientific knowledge with ethical values and sustainable practices in everyday life. Sterling (2010) suggests a transformative educational approach, in which ecological literacy is integrated into the curriculum to shape environmental awareness and the ability to take action.

In Indonesia, ecological literacy is becoming increasingly relevant in the context of education policies oriented towards character development and literacy. Through the development of digital textbooks that incorporate ecological literacy, students are expected to gain a deeper understanding of the importance of protecting the environment and applying ecological concepts in their daily lives. This is in line with global efforts to raise awareness and action on environmental issues. Ecological literacy is an important skill that every individual must have in order to understand and take action that supports environmental sustainability. This literacy includes knowledge, skills, attitudes, and actions oriented towards ecosystem preservation. The implementation of ecological literacy in education can help shape a generation that is more concerned about the environment and able to face global challenges related to environmental issues. In Indonesia, ecological literacy can be integrated with local wisdom to create a more contextual and relevant educational approach for the community.

Local Wisdom and Ecological Knowledge

Local wisdom represents a system of knowledge, values, and cultural practices that has developed over generations within a community as an adaptive response to its natural environment. According to Fatmawaty et al., (2023) local wisdom functions as a life philosophy that regulates harmonious relationships between humans, nature, and social life. In an ecological context, local wisdom not only encompasses cultural aspects but also presents ecological strategies passed down across generations to maintain the sustainability of natural resources.

Local ecological knowledge forms an essential component of the local wisdom system. Various studies show that indigenous communities possess effective environmental management mechanisms, including water conservation, forest protection, traditional agricultural management, and symbolic rituals that

serve to maintain ecosystem balance (Berkes, 2018). Wibawa and Awaliah (2023) emphasize that such local knowledge represents a form of ecological intelligence among traditional societies, enabling them to preserve biodiversity through sustainable practices.

The integration of local wisdom into education is regarded as having a positive impact on enhancing students' environmental literacy and ecological understanding. (Lubis et al., 2022) found that learning activities infused with the values of local wisdom can improve conceptual knowledge, cultural appreciation, and ecological awareness. From a pedagogical perspective, local wisdom-based learning positions learners' socio-cultural experiences as the foundation for understanding ecological concepts, making the learning process more contextual and meaningful.

Textbooks as a Medium for Ecological Education

Ecological literacy involves many disciplines because environmental issues are complex. Therefore, in order to instill an attitude of caring for the environment, stimulation is needed through a learning process that involves various subjects. Indonesian language subjects can be a means of strengthening ecological literacy in secondary school students. This is in line with the research by Neina et al. (2023) who states that efforts to preserve the environment can be made by integrating environmental values through Indonesian language lessons. This is reinforced by the Regulation of the Minister of Education, Culture, Research, and Technology of the Republic of Indonesia Number 12 of 2024, which states that the total number of teaching hours (JP) per year for Indonesian language subjects at the junior high school level is the highest among other subjects, namely 216 JP. This means that Indonesian language subjects have a greater share in efforts to strengthen ecological literacy.

Sumarwati's (2022) Research results show that traditional ecological knowledge (TEK) by the communities on the slopes of Mount Lawu is utilized as a means of food security. Then Hosen et al. (2020) argues that the people of Sarawak, Malaysia, preserve traditional ecological knowledge through cultural festivals and oral traditions passed down from generation to generation as a guide for adapting to climate risks and enhancing socio-ecological resilience. Then, based on Acharibasam and McVittie's (2023) study, the results show that the cultural framework of local communities that respects, reciprocates, and takes responsibility for nature can be integrated into environmental education in schools because it has the potential to improve human relations with the environment. Research conducted Makondo and Thomas (2018) providing specific and contextual evidence of indigenous knowledge related to climate change adaptation. Integrating unique and specific indigenous knowledge into other knowledge can be one of the best ways to implement more effective and sustainable climate change adaptation strategies in certain indigenous communities.

Method

Research Context

The textbooks selected in this study were those used by students in Central Java province. Based on the observation results, three textbooks are used by students. All three textbooks refer to the same curriculum, namely the Merdeka

curriculum. The difference between the three textbooks is in their publishers; one book is published by the government, while the other two are published by non-government publishers. The following table shows the profiles of the three books analyzed.

Table 1. Coursebook Profile

Title of The Book (Code)	Curriculum	Publisher
<i>Bahasa Indonesia (BI)</i>	Latest curriculum	Government
<i>Mahir Berbahasa Indonesia (MB)</i>	Latest curriculum	Non-government (Erlangga)
<i>Cakap Berbahasa Indonesia (CB)</i>	Latest curriculum	Non-government (Yusdhistira)

Table 2. Summary of Methods

Aspects of data analysis	Methods of data analysis	Data source
Aspect of local wisdom	Determining six dimensions: 1) local knowledge, 2) local values, 3) local skills, 4) local resources, 5) local decision-making, 6) local group solidarity	Textual samples (introduction, texts, assignments, exercises, questions)
Aspect of ecological literacy	Determining four main dimensions: 1) ecological knowledge, 2) ecological skill, 3) ecological attitudes, 4) ecological actions	from the three textbooks, namely BI, MB, and CB

Data analysis

This study uses document analysis to analyze the data. The three textbooks listed in Table 1 were analyzed using the theories of local wisdom and ecological literacy. These two theories were used to cross-check the integration of ecological local wisdom content in Indonesian language textbooks for Grade VII in Central Java. The local wisdom analysis utilized Sudikan's (2013) theory of the six dimensions of local wisdom, namely local knowledge, local values, local skills, local resources, local decision-making, and local group solidarity. The ecological literacy analysis utilized McBride et al., (2013) theory of the four dimensions of ecological literacy, namely ecological knowledge, ecological skills, ecological attitudes, and ecological action.

The analysis unit of this study is a sentence or paragraph. To maintain its reliability, two raters analyzed the textbooks separately and then discussed them to determine suitability. Table 2 shows a summary of data analysis methods. In addition to document analysis, this study also conducted interviews with Indonesian language teachers of Year 7 junior high school students in Central Java province. This data was used for data triangulation of the teaching books. Sixteen teachers from eight schools were interviewed. These teachers had professional certification from the Indonesian Ministry of Education and Culture.

Findings and Discussion

The analysis results of three textbooks in Central Java Province, which were analyzed using Sumarwati's (2022) TEK theory, indicate that their ecological

dimensions are not explicitly articulated or systematically integrated into the learning materials, although elements of local wisdom are present. Moreover, the identified local wisdoms originate from various provinces—such as Riau, Yogyakarta, Aceh, West Java, East Nusa Tenggara, and Papua—rather than from Central Java itself. This geographical mismatch poses challenges for contextual learning among teachers and students in the region. A closer look at the analyzed data can be seen in the explanation below.

Local Wisdom Aspect

Local wisdom content is most prevalent in CB, followed by BI and MB. CB is the book that most successfully disseminates local wisdom, while MB has not given significant attention to local wisdom. The following table shows the frequency of local wisdom dimensions in the three textbooks.

Table 3. Frequency of local wisdom dimensions

Local Wisdom Aspect	BI	MB	CB
Local knowledge	15	5	32
Local values	2	1	2
Local skills	2	-	5
Local resources	3	-	7
Local decision-making	-	-	-
Local group solidarity	1	-	1

The frequency table above shows findings of local wisdom originating from various provinces in Indonesia. However, it is surprising that no local wisdom originating from Central Java was found, even though all three textbooks are used in the Central Java area. The following are examples of local wisdom found in the three textbooks.

Example 1. BI page 23

Angka tujuh menunjuk kepada tujuh arah gunung di sekitar desa yang dipercaya sebagai pelindung desa.

(The number seven refers to the seven directions of the mountains surrounding the village, which are believed to protect the village.)

Example 1 above shows the local knowledge of the people of East Nusa Tenggara Province (NTT) about mountains as protectors of their villages. NTT Province also appears in the MB book in relation to the rare Komodo dragon. The community has its own knowledge about Komodo dragons, as in the following excerpt from the book.

Example 2 MB page 21

Masyarakat setempat menyebutnya "ora" atau "buaya darat".

(The local community calls it "ora" or "land crocodile.")

Local knowledge in example 2 is demonstrated through the local naming of Komodo animals by the local community. Furthermore, an example of local wisdom in the CB book is contained in the content on the manufacture of Asmat tribe transportation tools in the form of dugout canoes, as quoted below.

Example 3. CB page 17

Seperti sama-sama kita ketahui, masyarakat suku Asmat terkenal dengan hasil ukirannya yang unik. Demikian halnya dalam pembuatan perahu lesung ini. Perahu lesung dikerjakan dengan teknik yang halus, diukir, dan dicat.

(As we all know, the Asmat tribe is famous for its unique carvings. This is also true of the construction of these dugout canoes. Dugout canoes are crafted using delicate techniques, carved and painted.)

Example 3 above shows the local skills of the Asmat people in the carving technique used to make dugout canoes. The Asmat tribe itself comes from the province of South Papua, which shows the diversity of the regions of origin of local wisdom in the textbooks used by students.

The frequency of the regions of origin of local wisdom contained in the books is shown more clearly in the following figure.

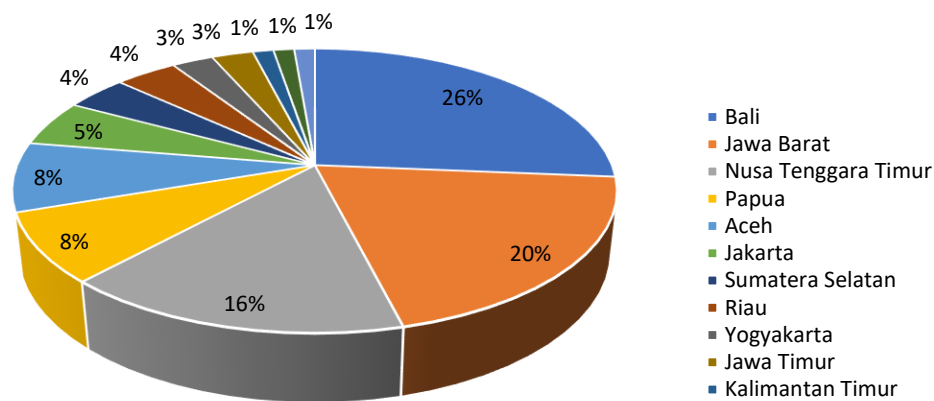


Figure 1. Distribution of Provinces Representing the Origins of Local Wisdom

In Figure 1, it can be seen that there is no local wisdom content originating from Central Java province. Most of the local wisdom content comes from Bali province, followed by West Java, East Nusa Tenggara, Papua, Aceh, Jakarta, South Sumatra, Riau, Yogyakarta, East Java, East Kalimantan, Maluku, and North Sumatra. The local wisdom content, which originates from various provinces in Indonesia, is in line with the target audience, namely all seventh-grade junior high school students in Indonesia. However, based on interviews with teachers in Central Java province, information was obtained regarding obstacles due to content originating from outside Central Java, namely that students had difficulty understanding the content. Teachers had to provide contextual understanding at the beginning of the lesson, which meant that additional time was needed for this.

Ecological Literacy Aspect

The dimension of ecological literacy was found in all three textbooks, and each book also contained the four dimensions of ecology, namely ecological knowledge, ecological skills, ecological attitudes, and ecological actions. Findings

on ecological literacy were not limited to content containing local wisdom, so the findings obtained were more numerous than those for content containing local wisdom. The frequency of the ecological dimensions in the three books can be observed in detail in the following table.

Table 4. Frequency of ecological dimensions			
Ecological Literacy Aspect	BI	MB	CB
Ecological knowledge	25	66	27
Ecological skill	8	6	5
Ecological attitudes	14	9	8
Ecological actions	4	3	7

Previously, it was explained that local wisdom was most frequently found in CB and least frequently in MB. In terms of ecological literacy, it was most frequently found in MB, followed by CB and BI. Most of the data in each book was on the dimension of ecological knowledge. The following are examples of quotations containing ecological literacy in the three textbooks.

Example 4. BI page 106

"Kami melakukan kampanye dan pendampingan pembalajaran rehabilitasi mangrove hingga pengolahan makanan berbahan baku mangrove untuk meningkatkan ekonomi masyarakat pesisir," jelas Mahtub Murtiyoso yang menjadi Kemangteer (sebutan untuk volunteer KeSeMat)

"We conduct campaigns and provide guidance on mangrove rehabilitation and the processing of mangrove-based foods to boost the economy of coastal communities," explained Mahtub Murtiyoso, a Kemangteer (a term for KeSeMat volunteers)

Example 4 above is an example of ecological behavior contained in the news text material. Example 4 shows the actions of volunteers in a mangrove ecosystem study group in Central Java. Below is example 5 from MB.

Example 5. MB page 144

Sudah seharusnya kita semua berbondong-bondong mengulurkan bantuan kepada pengungsi banjir.

We should all come together to extend a helping hand to flood refugees.

The quotation in example 5 shows an ecological attitude, namely an appeal to help victims of natural disasters in the form of floods. The quotation is also contained in the news text material. Next is an example from the CB book as follows.

Contoh 6. CB page 174

Para murid diajarkan menanam mulai dari nol. "Kami bikin pupuknya dari kotoran kambing, kasih pupuknya, ditanam, terus cabuti rumput juga," ujar Melsa, siswi kelas 4 B SDN Bongan.

The pupils are taught how to plant from scratch. "We make fertilizer from goat manure, apply the fertilizer, plant the seeds, and then pull out the weeds," said Melsa, a Year 4 pupil at SDN Bongan Primary School.

Example 6 shows the dimension of ecological skills in the form of the ability to make fertilizer from animal manure. These ecological skills are also contained in the news text. Content that contains ecological literacy also comes from various regions in Indonesia, such as content on local wisdom. In addition, Central Java appears in the news text material about the actions of the mangrove ecosystem study group.

Ecological local wisdom in Indonesian language coursebooks in Central Java

The ecological literacy presented in BI appears to be separate from local wisdom. The ecological literacy in the book is presented without any connection to local wisdom, both in terms of knowledge and local practices in the area. This shows that local wisdom and ecological literacy in the textbook appear to be presented separately in different chapters and themes. As explained earlier, most of the local wisdom data is found in Chapter I, *Jelajah Nusantara* (Exploring the Archipelago), in the descriptive text material. Meanwhile, ecological literacy is mostly presented in Chapter IV, *Aksi Nyata Para Pelindung Bumi* (Real Action by Earth Protectors), in the news text material about environmental awareness and natural disasters. No text fully links local wisdom and ecological literacy in this textbook. Similarly, in MB, the presentation of material containing local wisdom is separate from ecological literacy. As with BI, MB does not yet present ecological literacy material based on local wisdom, either in the context of Indonesia or Central Java. Findings in CB show that there is ecological literacy data based on local wisdom, but the environmental context presented is outside the province of Central Java.

The findings of this study reveal several important issues related to the use of local wisdom and ecological literacy in Indonesian language textbooks in Central Java. First, the absence of Central Javanese local wisdom in the three textbooks indicates a disconnection between students and their immediate cultural environment. In fact, several studies in culture-based education (Al-Madia & Ichsan, 2022; Garrard, 2012) emphasize that cultural context is very important for developing learning engagement, conceptual understanding, and a sense of ownership of the learning material. Thus, the use of local wisdom from other provinces without presenting local culture has the potential to create pedagogical distance between students and the material.

Secondly, although Sumarwati's (2022) TEK theory emphasizes the importance of integrating ecological knowledge with local knowledge, the three textbooks still present these two elements separately. This pattern shows that the concept of local wisdom is not yet understood as an ecological entity that lives in the cultural practices of the community. Local wisdom is only positioned as descriptive cultural information, not as a source of ethics, practices, or ecological

strategies that can be transformed into learning. This indicates that the textbook approach has not adopted the "ecologically embedded local wisdom" paradigm, namely local wisdom as ecological knowledge practiced in the relationship between society and nature.

Third, the dominance of ecological literacy in MB compared to BI and CB indicates that ecological content tends to be directed towards instilling general environmental awareness. However, because it is not connected to the local cultural context, students' critical ability to read ecological issues based on their living space is still limited. Students learn only at the conceptual level, not in terms of ecological meaning in everyday life.

Fourth, the diversity of local wisdom in textbooks actually opens up opportunities for multicultural learning. However, without proper context, students find it difficult to understand local contexts that are far removed from their reality. Teachers also need to provide additional scaffolding to bridge this understanding. This situation shows that textbook-based learning has not yet achieved the principle of place-based education, which is learning that uses the local environment as a starting point for understanding global concepts.

Fifth, the analysis results show a general pattern that ecological literacy appears most frequently in news texts, while local wisdom is more often found in descriptive texts. This confirms that textbooks have not been designed for text selection based on integrative strategies, but rather based on text type. In fact, theme-based integration, rather than text type, can be more effective in linking the concepts of ecological literacy and local wisdom.

The findings of this study show that Grade VII Indonesian language textbooks have not fully utilized the potential of local ecological wisdom as a means of strengthening ecological literacy and introducing local culture to students. The gap between local wisdom content and ecological literacy indicates the need for a more context-sensitive textbook design based on ecolinguistics and ethnopedagogy theories. With this integration, Indonesian language learning will not only develop language skills but also shape stronger ecological awareness and cultural identity in students.

Conclusion

This study concludes that the three Grade VII Indonesian language textbooks used in Central Java Province have not comprehensively integrated local ecological wisdom in accordance with Sumarwati's (2022) TEK framework. Although local wisdom content is found in all three books, it originates from other provinces and does not feature the local wisdom of Central Java, thereby reducing the contextual relevance of the material for local students. This condition indicates a gap between the need for local culture-based learning and the content provided by national textbooks. Furthermore, although ecological literacy appears consistently through its four dimensions—knowledge, skills, attitudes, and ecological action—the presentation is not linked to local wisdom and is mostly placed in a national or other provincial context. The separation between local wisdom and ecological literacy indicates that textbooks have not adopted an integrative approach that views local wisdom as an inherent part of the ecological knowledge of the community. These findings emphasize the need for textbook designs that are more sensitive to the local context, particularly by presenting the local wisdom of Central Java, which contains

ecological values. The integration of local wisdom and ecological literacy has the potential to not only increase the relevance of the material for students but also strengthen culture-based learning, place-based education, and the formation of ecological awareness from an early age. Thus, the results of this study provide an important basis for curriculum policy development, textbook refinement, and further research on the integration of local ecological wisdom in Indonesian language learning.

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PROBLEM-SOLVING PROCESS OF PRE-SERVICE MATHEMATICS TEACHERS IN STATISTICS

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Received: 30 October 2025; Accepted: 22 December 2025

Abstract

Problem-solving skills are essential for pre-service mathematics teachers as a foundation for guiding students in addressing mathematical challenges. However, students' problem-solving abilities in statistics courses remain relatively low. This study aims to analyze the problem-solving processes of pre-service mathematics teachers in a statistics course at Universitas Muria Kudus, Indonesia, based on their levels of problem-solving ability. Employing a qualitative-exploratory design, data were collected through statistical problem-solving tests and in-depth interviews, and then analyzed using Miles and Huberman's qualitative framework, which involves data reduction, data display, and conclusion drawing. Thirty-three students participated and were categorized into five ability levels. The results indicate that students with very high abilities demonstrated systematic reasoning, accurate hypothesis testing, and reflective evaluation. Students with high abilities completed calculations correctly, but often neglected modelling and identification of known elements. Those with moderate abilities could represent and solve problems, but they often skipped strategic planning. Meanwhile, students with low and very low abilities relied mainly on procedural computation without conceptual understanding. The study provides valuable insights for improving pedagogical strategies to strengthen statistical problem-solving competence among pre-service mathematics teachers.

Keywords: mathematical thinking, pre-service teachers, problem-solving, qualitative analysis, statistics education

Introduction

Mathematics is the mother of all branches of science and the basis of all scientific research, as most scientific and engineering problems require mathematics to be solved (Genc & Erbas, 2019; Kenedi et al., 2019; Muhtadi et al., 2018). Mathematics can be described as a formal science that uses symbolic language to study concepts such as numbers, structure, variation, and space. Today, mathematics is used in various fields, from engineering to medicine, and is taught as a compulsory subject for primary schools in many countries (Lee, 2017; Rahman & Ahmar, 2016). One of the main focuses of learning mathematics is problem-solving ability (Ai Hui et al., 2020; Alfin et al., 2019; Foshay & Kirkley, 2003; Jonassen, 2010; Susantini et al., 2016). Problem-solving skills are important to be developed in the curricula of the 21st century (Aydogdu & Kesan, 2014; Shabrina & Kuswanto, 2018) due to one of the main focuses of learning mathematics being



problem-solving skills (Ai Hui et al., 2020; Foshay & Kirkley, 2003; Jonassen, 2010). Learning mathematics may never be meaningful without problem-solving (Maf'ulah & Juniati, 2020).

Problem-solving ability is the ability to solve routine and non-routine problems, both applied and non-applied, in the field of mathematics (Lestari & Yudhanegara, 2017). Finding solutions to problems, or problem-solving, occurs through higher-order thinking skills (Nitko & Brookhart, 2011). Problem-solving requires thinking skills, including observing, reporting, describing, analyzing, classifying, interpreting, criticizing, predicting, drawing conclusions, and generalizing (Moore, 2012). Problem-solving ability is the ability to solve routine and non-routine problems, both applied and non-applied in the field of mathematics (Lestari & Yudhanegara, 2017).

Many experts have suggested stages/strategies/problem-solving steps. Polya suggests four steps of problem-solving, which have been widely used, namely understanding the problem, designing a plan to solve the problem, implementing the plan, and reflecting on the problem (Lee, 2017). Sternberg (Nguyen, 2009) reveals that a person's cycle in solving problems includes activities: (1) identifying the problem, (2) defining the problem, (3) constructing a strategy to solve the problem, (4) organizing information about the problem, (5) allocating resources and sources, (6) monitor problems, and (7) evaluate problem-solving. Problem-solving is a process that requires higher-order thinking skills. To be able to solve problem-solving problems, students use the stages: reading and understanding, analyzing and planning, organizing a strategy or organization on particular cases, solving the problem, confirming the process, and accepting the answer (Pujiastuti et al., 2018). In this study, the problem-solving steps that will be used as a reference for process analysis are: (1) read and understand the problem; (2) make mathematical models; (3) representing the problem; (4) finding the goal; (5) constructing problem-solving strategies; (6) solve the problem, and; (7) confirming the answer.

It is also important to develop problem-solving skills for students. Prospective mathematics teacher students need to understand and learn about the ability to design learning, implement learning, and evaluate learning outcomes, especially to explore problem-solving, so that later, after becoming a teacher, they can learn well and professionally (Nugroho et al., 2020). The reality on the ground shows that the problem-solving ability of prospective mathematics teacher students at Universitas Muria Kudus is still low. This is based on the results of the problem-solving ability test given to prospective teacher students. The test results showed that only 33% of students scored above the minimum criteria, and the remaining 67% of students scored below. Based on the results of interviews with prospective teacher students, it is known that the causes of their low problem-solving abilities include: (1) students have not been able to develop their ability to solve problems; (2) not familiar with non-routine questions; (3) difficulty in solving the given mathematical problem.

Seeing the importance of problem-solving skills, the researchers analyzed the statistical problem-solving process of students in terms of problem-solving abilities. The purpose of this study was to analyze the problem-solving process of research statistics courses from students of the mathematics education study program at Universitas Muria Kudus in terms of mathematical ability.

Method

This research is qualitative-exploratory research. The researcher conducted an exploration of the students of the major in Mathematics Education at Universitas Muria Kudus. A total of 33 students were involved in this study. Students are given a problem-solving ability test in the statistics course, which is then grouped into 5 categories based on the test results. The next research step is to choose 1 subject from each problem-solving category who can provide information consistently. In-depth interviews were conducted on research subjects so that information was obtained about students' thinking processes in solving problems.

The instruments used in this research are problem-solving test result documents and interview sheets. The statistical problem-solving ability test consists of five questions in the form of a description. The interview sheet contains questions that contain students' thinking processes in solving problems based on problem-solving steps, namely: (1) read and understand the problem; (2) make mathematical models; (3) representing the problem; (4) finding the goal; (5) constructing problem-solving strategies; (6) solve the problem, and; (7) confirming the answer.

Data were obtained from the results of problem-solving ability tests and in-depth interviews with research subjects. The data from the problem-solving ability test are then grouped into the five categories referring to the rating scale in Table 1 (Arikunto, 2013).

Table 1. Criteria for Problem-solving Ability Test Score

Range	Category
$80 \leq score \leq 100$	Very High
$65 \leq score \leq 79.99$	High
$55 \leq score \leq 64.99$	Medium
$40 \leq score \leq 54.99$	Low
$0 \leq score \leq 39.99$	Very Low

The credibility of the data obtained by triangulation techniques, namely, interviews, was compared and explored to compare and explore information about students' problem-solving steps. The data analysis technique used refers to Miles et al. (2014), namely data reduction, data presentation, and conclusions.

Findings and Discussion

The results of the statistical problem-solving ability test conducted on 33 students are presented in Table 2. The results of the test showed that there were 7 students with very high and high categories, 2 students who got the medium category, 5 students in the low category, and 12 students belonging to the very low category.

Table 2. Test Results of Problem-Solving Ability

Category	Number of Students
Very High	7
High	7

Medium	2
Low	5
Very Low	12

The test results indicate that the statistical problem-solving ability of students in the mathematics education study program is still low. The following are the results of the analysis of student problem-solving processes in each category.

Problem-Solving Process of Students with Very High Problem-Solving Ability

Based on the analysis of research data shows that students have very high mathematical problem-solving abilities (PS1 subject) in each stage of problem-solving (understanding the problem, developing a plan of completion, implementing a plan of completion, and re-examining). At the stage of reading and understanding the problem, the PS1 subject was able to analyze the problem by writing down what was known and asked in the question.

From the answers of PS1 subject, it was discovered that students with very high problem-solving abilities can understand problems. It was shown that students could find out the dependent variable and the independent variable in the problem. The ability to understand problems by PS1 subject was influenced by experiences in working on problem-based questions.

An individual's ability to identify a given problem is influenced by the individual's own experience and knowledge (Allport, 1960). Experience and knowledge stored in memory will affect each individual in response to the stimulus that comes (Gagne, 1985). Experience will give the shape and structure of objects described by the senses, while knowledge will give meaning to objects, individuals, and people involved in the answers to the available answers in the form of individual attitudes and behavior towards existing objects (Allport, 1960). Gagne (1985) also explains that a person's understanding depends on how much the individual has studied the stimulus or previous learning.

In the stage make mathematical model, the student tried to find keywords and then wrote them down in a mathematical model. The indicator at this stage was that students were able to write examples of sentence questions into mathematical models. This is in accordance with Figure 1. PS1 subject assumed Y as the dependent variable, X_1 and X_2 as the independent variables.

The next stage was representing the problem. PS1 subject could choose the right representation according to the problem presented. The representation used by PS1 subject was a mathematical expression symbolized by x and y , and they used a table to write down the elements needed to solve the problem. In this stage, finding the goal, the student began to formulate the goals of problem-solving. PS1 subject was able to write down what was asked in the question and the research hypothesis proposed by the question.

At the stage of constructing problem-solving strategies, the subject could write down the sequence of strategies used in a coherent and precise manner, starting from the selection of statistical tests, processing the known elements of the questions, and setting test criteria. Problem-solving construction is a mental activity in finding information and linking the information possessed with previous information to help solve the problems encountered (Setyawan & Rahman, 2013).

Constructing problem-solving in learning mathematics always links old knowledge with new knowledge to help solve problems (Subanji & Supratman, 2015).

In the sixth stage of solving the problem, PS1 subject worked on problem-solving problems by performing mathematical calculations correctly, according to formulas, strategies, and the selected representation. At this stage, the subjects performed calculations assisted by SPSS, and the results obtained were correct. This shows that the PS1 subject was able to perform mathematical calculations accurately and correctly.

The seventh stage was confirming the answer, which is the last process in solving mathematical problems. The indicator in this stage is that students find the final answer in accordance with the purpose of the question and are able to express the answer in the interpretation of the question, no longer in the form of symbols or mathematical models. Students with very good categories conclude the answers at the end, and the conclusion is correct. Figure 1 is the PS1 subject's answers in the process of solving statistical problems.

Diketahui : Kemampuan pemecahan masalah (y), kemandirian belajar (x_1), Keterampilan pemecahan masalah (x_2)						
Ditanya : Apakah terdapat pengaruh yang signifikan antara kemandirian belajar dan keterampilan pemecahan masalah terhadap kemampuan pemecahan masalah ?						
Jawab :						
1. Langkah - langkah pengujianya.						
1. Uji normalitas dan homogenitas $\rightarrow$ data diasumsikan normal dan homogen.						
2. Menentukan hipotesis yang akan diuji						
H_0 : Tidak terdapat pengaruh yang signifikan antara kemandirian belajar dan keterampilan pemecahan masalah terhadap kemampuan pemecahan masalah						
H_1 : Terdapat pengaruh yang signifikan antara kemandirian belajar dan keterampilan pemecahan masalah terhadap kemampuan pemecahan masalah						
3. Melakukan Uji Regresi Linier Ganda $\rightarrow$ dapat dilihat pada tabel ANOVA						
ANOVA						
	Sum of					
Model	Squares	df	Mean Square	F	Sig.	
1 Regression	2877.357	2	1438.679	3.751	.042	
Residual	7287.722	19	383.564			
Total	10165.079	21				
4. Kriteria pengujian						
Jika Sig. > α maka H_0 diterima						
Jika Sig. < α maka H_0 ditolak						
5. Kesimpulan						
Karena Sig. = 0.042 < α = 0.05 maka H_0 ditolak dan H_1 diterima.						
Sehingga " Terdapat pengaruh yang signifikan antara kemandirian belajar dan keterampilan pemecahan masalah terhadap kemampuan pemecahan masalah. "						

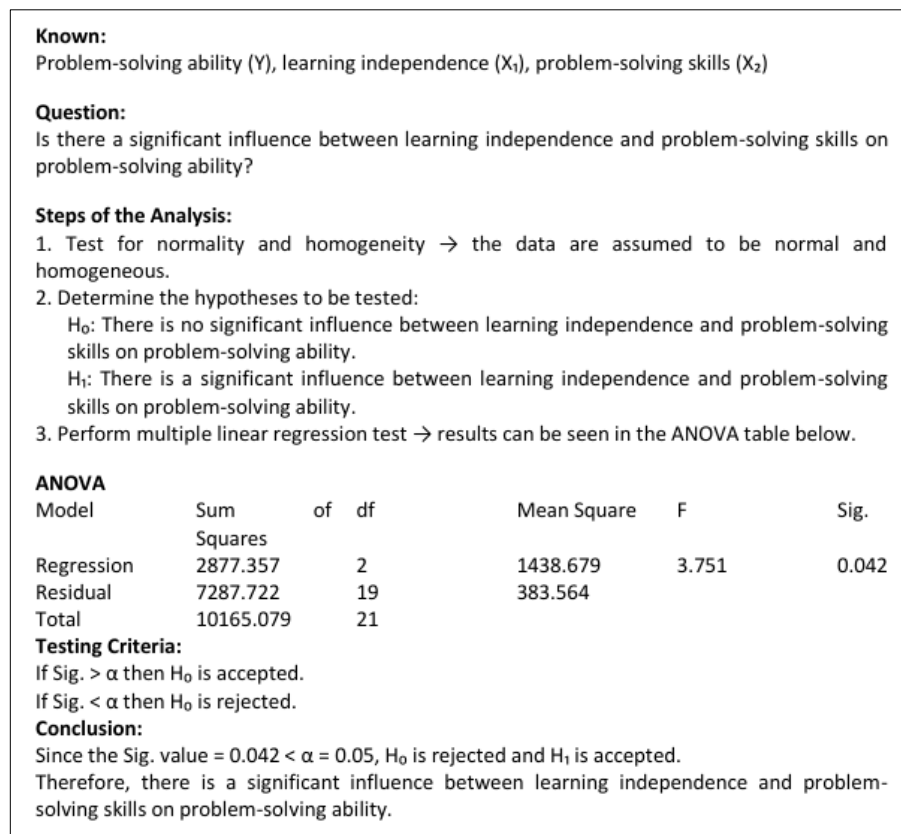


Figure 1. Answers of PS1 Subjects (Translated)

Based on the analysis results of PS1 subject's problem-solving process, it is known that the statistical problem-solving process is carried out very well. All problem-solving processes can be carried out well. PS1 subject was able to solve problems by formulating hypotheses, determining statistical tests, H₀ acceptance criteria, performing calculations, and interpreting results. This situation shows that students can solve problems by involving excellent abilities in realizing and regulating their thinking processes (Pramono, 2017). Students with excellent mathematical problem-solving skills have a positive effect on the development of their creativity in non-routine problem-solving (Cho & Kim, 2020).

Problem-solving Process of Students with High Problem-solving Ability

The results of research data analysis show that students with high problem-solving skills are successful in each stage of problem-solving. PS2 subject is a student with high category problem-solving abilities. The first stage of the problem-solving process is to read and understand the problem. PS2 subject was able to analyze the problem by writing down what was known and asked in the question. PS2 subject understood the problem by reading the problem several times, even though he did not write down what was known in the problem. PS2 subject was able to identify the problem in question by expressing what was understood about the problem.

In the stage of making the mathematical model, PS2 subject did not explain in detail the modelling of variables Y, X₁, and X₂. PS2 subjects were able to choose the right representation according to the questions presented. The representation

used by the PS2 subject was a mathematical expression symbolized by x and y . The mathematical expression consists of algebraic and numeric symbol language (Nerit & Amit, 2004). In the finding the goal step, the PS2 subject was able to determine the goals to be achieved in the problem by writing down the goals correctly and correctly.

PS2 subject was able to construct problem-solving strategies to solve problems. PS2 subject wrote down the steps of the strategy used in detail, and even wrote down the steps of using SPSS in detail. PS2 subject solved problems using calculations assisted by SPSS software. The results of the calculations carried out by PS2 subject were correct, and they completely wrote down the results of the SPSS calculation table in the answer. Thus, at the stage of solving the problem, PS2 subject with the high problem-solving category was able to do the calculations correctly. At the confirmation stage, PS2 subject was able to conclude the answer in the form of a description, not just the results of the hypothesis acceptance criteria. Based on this, it was concluded that PS2 subject was able to confirm the correct answer.

Based on the results of the analysis of the PS2 subject's problem-solving process, complete metacognition activities, namely planning, monitoring, and reflection, starting from understanding the problem to the last stage, namely the evaluation of the solution, have been carried out properly. The entire problem-solving process could be passed. However, some problem-solving processes were less than optimal in writing the answer. This situation shows that the subject can solve problems by involving good abilities in realizing and regulating their thinking processes.

Problem-solving Process of Students with Medium Problem-solving Ability

PS3 subject is a student with a moderate ability in mathematical problem-solving. Figure 2 shows the steps for solving statistical problems carried out by PS3 subject.

5.) Ujilah apakah terdapat pengaruh yang signifikan antara kemandirian belajar dan keterampilan pemecahan masalah siswa?

Jawab =

Model Summary							
Model	R	R Square	Adjusted R Square	Sig. of F	df1	df2	
1	0,283	0,080	0,034	2,770	1	20	

ANOVA						
Model		Sig. of Square	df1	Mean Square	F	Sig.
1	Regression	13,355	1	13,355	1,711	0,202
	Residual	153,417	20	7,671		
	Total	166,773	21			

Dari hasil output yg pertama didapatkan $(k) = 0,283$ dg koefisien determinasi di $(k \text{ square}) = 0,080 = 8\%$.
 Dari hasil output yg kedua nilai sig didapatkan $0,202 > 0,05$ maka korelasi signifikan, maka korelasi signifikan dg pengaruh 8%.

Question:
Test whether there is a significant influence between learning independence and students' problem-solving skills.

Model Summary							
Model	R	R Square	Adjusted R Square	Std. Error	F Change	df1	df2
1	0.283	0.080	0.034	2.770	1.741	1	20

ANOVA						
Model	Sum of Squares	df	Mean Square	F	Sig.	
Regression	13.355	1	13.355	1.741	0.202	
Residual	153.417	20	7.671			
Total	166.773	21				

From the first output, it is obtained that $r = 0.283$ and the coefficient of determination (R^2) = 0.080 = 8%. From the second output, the Sig value obtained is 0.202 > 0.05, meaning that the correlation is not significant. Therefore, the correlation is not significant, and the influence is 8%.

Figure 2. PS3 Subjects' Answers (Translated)

At the stage of reading and understanding the problem, PS3 subject did not write down what was known in the problem, but wrote down what was asked in the question. PS3 subject felt that he did not have time to write down the known elements of the questions because they would spend their time doing calculations. PS3 subject also did not make an example of a question sentence into a mathematical model. PS3 subject only represented problems with the same words as the given question sentences. In finding the goal, PS3 subject was able to know the goals to be achieved in the question, but did not write them down in the answer sheet. PS3 subject also did not write a problem-solving strategy, but he felt sure that the strategy was enough in his imagination. In the stage of solving the problem, PS3 subject did the calculations with the help of Ms. Excel, but the final answer was still incorrect. The accuracy of PS3 subject lacked data input, and the formulation in Ms. Excel caused the wrong answer. PS3 subject could confirm the answer; however, because the problem-solving process was wrong, the results obtained at the confirmation stage were still incorrect.

Based on the results of the analysis of the students' problem-solving process in the medium category, the PS3 subject missed several stages of problem-solving, namely reading and understanding the problem, making mathematical models, finding the goal, and constructing problem-solving strategies. PS3 subject tend to immediately solve problems without making a settlement strategy. PS3 subject's planning in solving immature problems caused the PS3 subject to be less able to control the calculations carried out. Hypothesis testing will be less than optimal if the stages are not carried out systematically and coherently.

Problem-solving Process of Students with Low Problem-solving Ability

PS4 subject is a student who has a low problem-solving ability. In the statistical problem-solving process, many troubleshooting steps were not performed by the PS4 subject. The student only performed calculations that were presented in tabular form and drew conclusions based on the interpretation of the results. A PS4 subject admitted that he was nervous when he received a question, so he immediately thought about how to solve it. PS4 subject was not confident in

statistics courses and did not know that the hypothesis testing steps needed to be completed.

At the read and understand the problem stage, the PS4 subject did not analyze the problem properly. PS4 subjects do not write down what is known and asked in the question. Based on the results of interviews with other PS4 subjects, information was obtained that PS4 subjects were confused about the questions because three data points were presented and had to analyze which ones were the dependent and independent variables before taking the test.

At the make a mathematical model stage, the PS4 subject did not write down an example of a question sentence into a mathematical model. The representation used by the PS4 subject is the SPSS output calculation table. However, the PS4 does not use any form of representation to present the problem. Tiffany et al., (2017) stated that mathematical ideas can be expressed in writing in the form of pictures, diagrams, or tables.

At the stage of finding the goal, the PS4 subject did not write down what was asked in the question. The results of the interview showed that the PS4 subject felt that they knew what the questions were asking, but did not write it down in the answer sheet. After confirmation, the PS4 subject was unable to distinguish the dependent and independent variables intended by the question. PS4 subjects only know that the statistical test to be used is the regression test.

In the stage of constructing problem-solving strategies, the PS4 subject has not yet written a comprehensive solution strategy. This is because there was an error in the previous stage, so that in the stage of constructing problem-solving strategies, it was also wrong. If students in the early stages of the modelling process have not been able to solve the problems, they cannot proceed to the next stage (Wijaya et al., 2014).

At the stage of solving the problem, the PS4 subject has not gotten the results correctly and precisely, even though they have used SPSS as a statistical tool. The seventh stage of problem-solving confirmed the answer. PS4 subject did not confirm the answer correctly. This is because the results obtained by the PS4 subject in the problem-solving process were wrong and resulted in the confirmation process of answers. Confirmation of answers was only done by rewriting the results, not interpreting the results in accordance with the intended purpose of the question.

Based on the results of the analysis, it can be said that the problem-solving process of students with low categories has not been completely implemented. Students stated that they did not understand the material being tested, so they had difficulty understanding questions that were different from practice questions. PS4 subjects do not identify problems and determine goals first, and even tend to do calculations without planning. The absence of the construction of a settlement strategy in the form of writing or in thought causes errors in the completion.

The difficulties experienced by students in the problem-solving category are less due to the low ability of students to solve problems. Suharta (2016) said that students tend to solve problems by paying attention to the numbers, regardless of the intent of the question. The difficulty in determining a problem-solving plan is also supported by the opinion of Lidinillah (2008) that educators usually provide the same strategy for solving problems.

Problem-Solving Process of Students with Very Low Problem-Solving Ability

PS5 subjects are students who have very low problem-solving skills. Based on the analysis of research data, it shows that students' ability to solve mathematical problems is very lacking in each stage of problem-solving. The following is the process of students with problem-solving abilities that are very lacking in problem-solving:

At the read and understand the problem stage, a PS5 subject read repeatedly but did not understand the problem. PS5 subjects were not able to analyze the problem, so they could not write down what was known and asked in the question. PS5 subjects also don't create mathematical models. PS5 subjects had difficulty representing problems because they thought the problems presented were difficult to understand. PS5 stated that in fact he did not understand the material being tested because he felt that statistics was a difficult subject. PS5 subjects could not distinguish the type of statistical test to be used in each different type of case. This was because students have not been able to bring mathematical knowledge to real situations.

In the finding the goal stage, the PS5 subject did not write down what was asked in the question. The same thing was also done by NS subjects at the stage of constructing problem-solving strategies. PS5 subjects have not written down the strategies used in problem-solving but have directly analyzed them using SPSS software. This was because NS subjects still had difficulty with writing strategies. After all, they were not familiar with non-routine questions. habits in practicing skills, in understanding and solving problems, need to be given to students (Abdillah & Budiarto, 2017). With practice and habituation to understand and solve problems, students will get used to and understand problem-solving strategies (Nurkaeti, 2018).

From the analyzed PS5 subject's answer sheet, he solved the problem directly at the problem-solving stage. The PS5 subject was able to write SPSS output, but the calculation result was wrong. This was because of the incorrect input data and the difficulty in determining the dependent and independent variables. The PS5 subject did not find a statistical problem-solving strategy; therefore, the risk of error in the questions increased. At the stage of confirming the answer, the PS5 subject made an error in interpreting the written SPSS output. He tended to be careless in making concluding answers and not in accordance with the purpose of the question. The PS5 subject felt that the written answer was not optimal, and he believed that the answer would be wrong.

Based on the analysis of the problem-solving process of students with very poor categories, it can be said that the problem-solving process carried out by the subject of the very low category in the research statistics course is still lacking in the problem-solving process. Students with very low categories have not been able to solve problems, causing errors in solving them. Students in the very low category were not familiar with non-routine questions, so they had difficulty solving problem-solving problems. So, it is necessary to get used to doing non-routine questions. When students are approached with a non-routine math problem, their reactions are more gentle, including body movements, and if the problem-solving time is long, the emotional response can be very intense (Díaz et al., 2018).

Conclusion

Based on the results and discussion, it can be concluded that students with very high statistical problem-solving skills can solve problems at all stages of problem-solving. Students also complete the task according to the stages of statistical hypothesis testing. Students in the category of high mathematical ability were able to complete calculations and interpret results, but did not write down the known elements, and did not do modelling. Students with a moderate problem-solving ability category can make mathematical representations, solve the problem, and confirm the answer. However, this subject missed several stages of problem-solving, namely reading and understanding the problem, making mathematical models, finding the goal, and constructing problem-solving strategies. They tend to do the calculations directly without making a plan. Subjects with low and very low categories also immediately completed calculations without understanding the problem and developing a settlement strategy first. Because the subject does not understand the problem, the calculations made are still wrong and tend to be arbitrary in interpreting the results.

Acknowledgement

Thanks are extended to the Directorate of Research and Community Service of the Ministry of Higher Education, Science and Technology of Indonesia for providing applied research grant funds with contract number 127/C3/DT.05.00/PL/2025.

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IMPLEMENTATION OF GENERATIVE ARTIFICIAL INTELLIGENCE AS CO-CREATOR TO ASSIST STUDENTS IN RESEARCH PROPOSAL WRITING

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Received: 8 December 2025; Accepted: 7 January 2026

Abstract

The development of Generative Artificial Intelligence (GenAI) technology has opened up new opportunities in the field of education, serving as a collaborative partner in the learning process. This study aims to explore the implementation of GenAI as a co-creator in assisting students in writing research proposals and students' responses to the implementation. This study is descriptive-qualitative research. The research subjects are students taking the Research Proposal course in the odd semester of 2025/2026 in the Economics Education Study Program, Sanata Dharma University. Data collection techniques include interviews and questionnaires. Result of this research are: 1) students use GenAI platforms such as ChatGPT, Claude, and Google Gemini as co-creators in various stages of research proposal writing, ranging from finding ideas, developing background, literature review, to proposal finalization; 2) Students have positive responses regarding the implementation of GenAI to assist students in writing research proposals. The positive responses are students feeling assisted in writing research proposals, students feeling confident and self-assured, students being able to write research proposals with better quality, and students having enough time to finish proposal. This research contributes to developing innovative learning that integrates artificial intelligence in education, while providing practical recommendations for educational institutions in adopting GenAI technology.

Keywords: co-creator, generative artificial intelligence, research proposal, students' responses

Introduction

The development of artificial intelligence (AI) technology based on Large Language Models (LLMs) has entered a transformative phase that substantially changes the landscape of knowledge production, academic practices, and the representation of human intellect. Since the introduction of GPT-3 in 2020 and followed by advanced models such as GPT-4, GPT-4.1, Gemini 1.5/2.0, Claude 3.x, and Copilot, generative AI (GenAI) has become one of the most disruptive technologies of the modern era (UNESCO, 2023; OECD, 2023). Not only functioning as a language processing tool, GenAI now acts as a collaborative agent capable of reasoning, composing arguments, providing methodological



justifications, generating literature syntheses, and reshaping the structure of academic discourse with near-human coherence.

In higher education, GenAI's ability to produce scientific text quickly and adaptively introduces a new paradigm into academic writing. Research proposal writing—which has traditionally been understood as a high-level cognitive process involving problem formulation, literature analysis, construction of theoretical frameworks, and methodological development (Creswell & Creswell, 2018)—is now subject to renegotiation due to the presence of GenAI as a co-creator. This phenomenon triggers an epistemological shift in how students understand, structure, and execute the research process.

Across various regions, studies show that students use GenAI in multiple stages of academic writing: from idea generation, topic exploration, formulation of research questions, drafting the background, literature search, methodological design, instrument development, to language revision and paraphrasing (Kasneci et al., 2023; Kohnke & Moorhouse, 2023). Pedagogically, this indicates that GenAI functions as a cognitive amplifier that enhances users' intellectual capacities (Daugherty & Wilson, 2018). However, this role simultaneously raises serious ethical and epistemic issues, including plagiarism, AI-generated hallucinations, computational bias, loss of human agency, and threats to academic integrity (Floridi & Chiriatti, 2020).

Conceptually, the use of GenAI in research proposal writing can be analyzed through the Technology Acceptance Model (TAM). Two principal constructs in TAM—Perceived Usefulness and Perceived Ease of Use (Davis, 1989)—are relevant to explaining students' motivations to integrate AI into academic writing. Recent research reports that students tend to accept GenAI when they perceive the tool as useful in speeding up writing, improving argument clarity, reducing cognitive load, and supporting literature structuring (Holmes et al., 2022). Nevertheless, this acceptance does not stand alone; it is influenced by perceived risks, such as plagiarism concerns, inaccuracies, and public or institutional perceptions about the legitimacy of GenAI usage (UNESCO, 2023).

Alternatively, theoretical approaches position GenAI not merely as a digital aid but as a partner in knowledge construction. The augmented intelligence paradigm emphasizes a symbiotic human–AI partnership in which AI expands cognitive capacity while still requiring supervision, epistemic control, and human verification (Shneiderman, 2020). Therefore, using AI in proposal writing is not only a technological issue but also an epistemological one that reshapes knowledge practices.

Challenges are more apparent in the Indonesian student context. Limited information literacy, lack of research experience, administrative academic burdens, and insufficient access to adequate academic guidance might make proposal writing a difficult process. The presence of GenAI becomes both an opportunity and a threat: on one hand, it can accelerate and improve writing quality; on the other, it can undermine authorship integrity if used without critical understanding.

Although global studies on GenAI use in higher education are rapidly expanding, there is a gap in micro-level research, particularly on how Indonesian students concretely utilize GenAI at different stages of research proposal writing. Additionally, there is a lack of studies that evaluate student perceptions using a comprehensive instrument encompassing usefulness, ease of use, collaboration

quality, ethical concerns, skill development, technical challenges, and long-term usage intentions.

Based on these conditions, this study was designed to provide an in-depth understanding of (a) patterns of GenAI use as an assistant and co-creator in students' research proposal writing, (b) student perceptions regarding usefulness, ease, challenges, risks, and ethical implications of GenAI use, (c) epistemological dynamics that emerge when students use GenAI during scientific reasoning, and (d) policy recommendations for ethical, safe, and productive GenAI integration in higher education. This approach is relevant because it contributes both theoretically and practically to understanding how generative technologies affect contemporary academic practices and how educational institutions can respond strategically to this phenomenon.

Method

This methodology section is organized to provide a comprehensive overview of the research design, participant characteristics, data collection instruments, and analytical procedures used. The explanations below summarize our prior discussions in full, complete form, and without condensation.

Research Design

This study uses an exploratory–descriptive mixed design, combining:

- a. A quantitative descriptive approach, used to analyze numerical patterns from questionnaire responses, compute mean scores for each dimension, and examine the distribution of AI usage by students in the context of research proposal writing.
- b. A qualitative thematic approach, used to explore students' subjective experiences regarding benefits, challenges, ethical perceptions, and their recommendations for using GenAI as a co-creator in academic writing.

This combined approach was chosen to capture the complexity of GenAI usage that is not only technical but also epistemological and ethical. The integrative model also allows the researcher to understand dynamics at the behavioral usage level, cognitive perception (Perceived Usefulness & Perceived Ease of Use), and value reflection (Academic Integrity Concerns).

Research Participants

Participants consisted of nine students from the Economics Education Study Program who were enrolled in the Research Proposal Writing course during the odd semester of the 2025/2026 academic year. All students had empirical experience using GenAI for academic purposes, particularly related to research proposal writing. Although the sample size is small, the research design is not intended for population generalization but to deeply explore the phenomenon of GenAI use in a specific learning context.

Research Instruments

The main instrument used was a structured questionnaire that comprehensively covered several key components, including information on the use of AI, students' perceptions of AI, and open-ended questions regarding the use of AI. The information on the use of AI covered the platforms used (ChatGPT,

Gemini, Copilot, and others), the frequency of use, and the academic activities assisted by AI.

The questionnaire in this study used a 1-5 Likert scale. This questionnaire was used to obtain information about students' perceptions of the use of AI in writing thesis proposals. These perceptions included the following seven components.

1. Perceived Usefulness (PU): measures the extent to which AI is considered helpful in accelerating, simplifying, or improving the research proposal writing process.
2. Perceived Ease of Use (PEOU): assesses ease of using AI platforms, learning prompts, and operating the system.
3. Collaboration Quality (CQ): evaluates the quality of human–AI interaction, including relevance of AI suggestions, context understanding, and adaptability to instructions.
4. Academic Integrity Concerns (AIC): assesses student concerns about plagiarism, originality, ethical AI use, and the risk of academic misconduct.
5. Learning & Skill Development (LSD): assesses the degree AI supports student learning, understanding methodology, proposal structure, and enhancing academic thinking.
6. Challenges & Barriers (CB): identifies technical and cognitive obstacles, such as AI hallucinations, source verification, access limitations, and subscription costs.
7. Future Intention to Use (INT): measures students' intention to continue using AI in future academic activities.

To delve into personal narratives, the instrument also included essay questions about the greatest benefits students perceived from AI use, difficulties or challenges they experienced, and recommendations for better AI usage in academic environments.

Instrument Validation

The instrument was developed based on current literature on AI use in education (Kasneci et al., 2023; Holmes et al., 2022) and the theoretical constructs of the Technology Acceptance Model (Davis, 1989). Internal consistency was estimated based on theoretical category structure rather than statistical testing, consistent with the exploratory nature of the study.

Data Sources and Collection Procedure

Data were obtained from the questionnaire that was collected from participants, observation of GenAI utilization in class activities, supporting documentation, and students' reflective notes. The data collection stages included:

1. Distribution of the questionnaire to all students in the relevant course.
2. Initial briefing on research objectives and ethical participation.
3. Collection of data via a digital questionnaire platform.
4. Processing responses in Excel for further analysis.
5. Compilation of descriptive and thematic results.

All participants gave voluntary informed consent.

Data Analysis Techniques

In this study, descriptive data analysis was carried out quantitatively and qualitatively. Quantitative descriptive analysis will be performed through calculation of mean scores for each dimension, graphical analysis: distribution of platforms used, frequency of AI use, comparison of means by dimension, and interpretation of patterns using TAM, previous literature, and local context. Whereas, the qualitative descriptive analysis was carried out using thematic content analysis with the following steps: (1) Repeated reading of all open responses, (2) Identifying important semantic units, (3) Coding initial themes (benefits, challenges, ethics, recommendations), (4) Grouping codes into higher-level thematic categories, (5) Composing comprehensive interpretive narratives based on augmented intelligence theory and AI ethics frameworks. Analysis was conducted without condensing explanations or simplifying meanings, in accordance with your request.

Data Validity and Credibility

To ensure data quality, the following approaches were used:

1. Method triangulation: integrating quantitative and qualitative data.
2. Theoretical triangulation: employing TAM, augmented intelligence, and AI ethics frameworks.
3. Critical reflection: unpacking student biases in AI use.
4. Peer debriefing (informal): consulting preliminary results with colleagues.

Methodological Limitations

The study has the following limitations: (1) Small number of participants (n = 9), (2) context limited to a single study program, (3) evaluative instruments not subjected to formal statistical validity testing, and (4) interpretations are contextual and non-generalizable. Nevertheless, for exploratory research, depth of narrative constitutes the study's primary strength.

Findings and Discussion

This section presents an in-depth analysis of patterns of Generative AI (GenAI) use by students, their perceptions regarding benefits and challenges, and the epistemological and ethical dynamics that arise. All results below are comprehensive syntheses of questionnaire data collected through the "AI Questionnaire (Responses).xlsx" file and conceptual elaborations grounded in relevant theory.

Patterns of GenAI Use by Students

Based on questionnaire responses, students used various GenAI platforms to support research proposal writing.

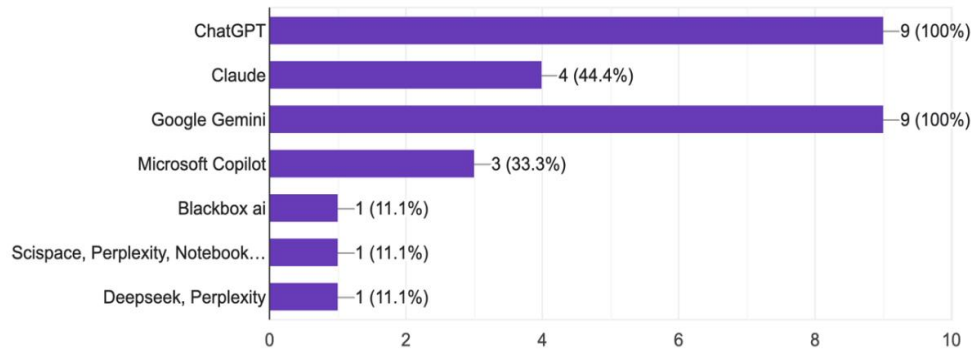


Figure 1. Platform Distribution

Based on Fig.1, ChatGPT is the dominant and most frequently used platform, Google Gemini as a secondary platform, Microsoft Copilot as an auxiliary tool, and some students used more than one platform interchangeably. This aligns with global findings that ChatGPT has the highest user penetration among students due to model stability, ease of access, and relatively advanced reasoning capabilities (Kasneci et al., 2023). Epistemologically, preference for certain platforms indicates that students begin to form epistemic trust toward particular AI systems—that is, they perceive certain systems as more credible, accurate, and easier to direct. In academic contexts, such epistemic trust can influence whether students accept or reject AI-supplied suggestions.

Based on the questionnaire results, students varied in terms of frequency of use of generative AI, as shown in Fig 2. Based on Fig 2, some students used AI daily, others 3–4 times per week, some 1–2 times per week, and others rarely. This result correlated with the level of difficulty students faced, the stage of proposal writing (initial phases tend to be most intensive), digital literacy skills, and students' readiness to use AI as a co-creator. Students who used AI daily were generally in active drafting phases and relied on AI for brainstorming, clarifying concepts, and language refinement.

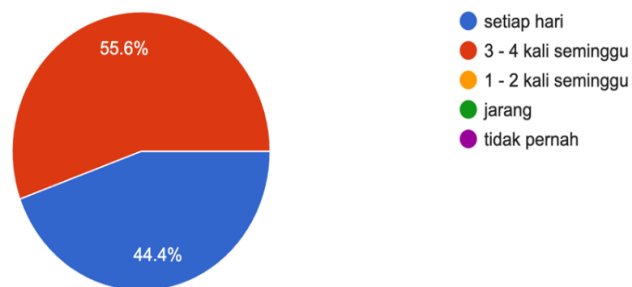


Figure 2. Frequency of GenAI Use

Quantitative Analysis by Instrument Dimensions

This section presents quantitative results across seven primary dimensions. The first result of the questionnaire was about the use of generative AI in preparing final project or thesis proposals. The results of this questionnaire showed that students used generative AI to brainstorm research ideas, formulate problem

backgrounds and research questions, conduct literature reviews, develop theoretical frameworks, design research methodologies, improve sentence structure, check grammar, paraphrase or reword, and create proposal outlines. These results are shown in Figure 3, where the highest mean is the use of generative AI to improve sentence structure (4.33) and the lowest mean is its use to formulate research questions (3.00).

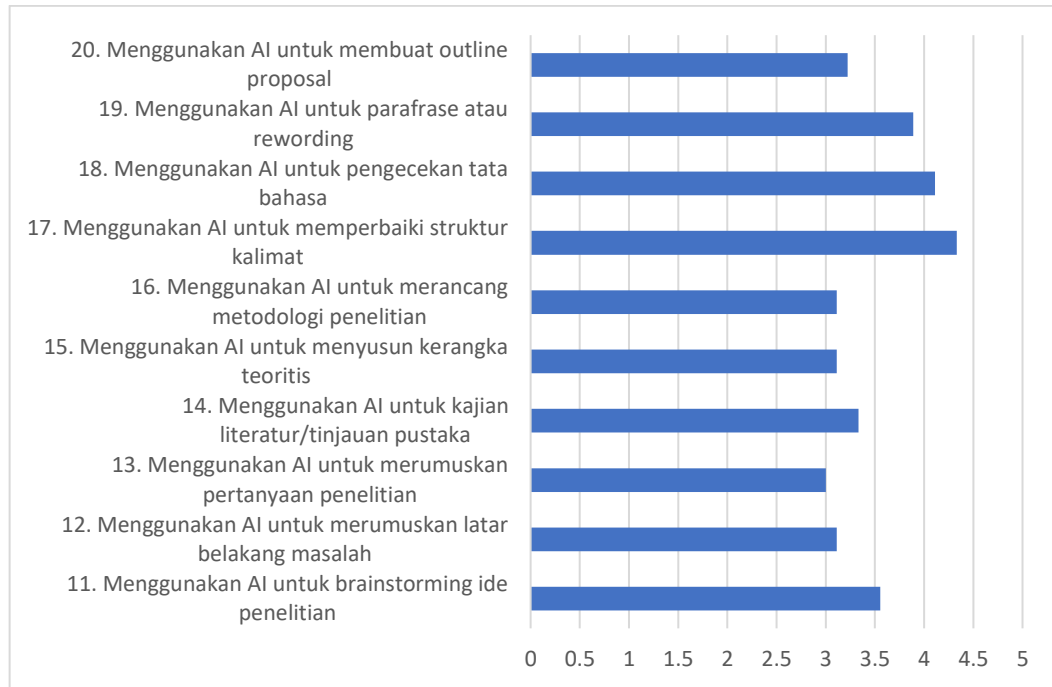


Figure 3. The Use of Generative AI in Writing Thesis Proposals

Perceived Usefulness (PU)

Based on the questionnaire results, the perceived usefulness of generative AI is shown in Fig 4. These results are based on 5 questions about perceived usefulness that were given, and we obtained a mean of 3.53, with the highest mean on Generative AI simplifies the process of brainstorming research ideas (4.00).

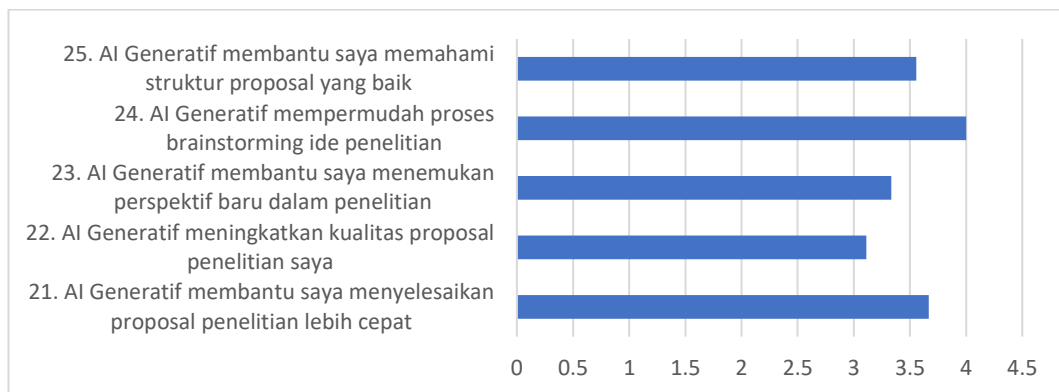


Figure 4. Perceived Usefulness of Generative AI

Students rated GenAI positively in terms of usefulness: AI speeds up writing, clarifies argument structure, provides alternative formulations, offers examples of theoretical frameworks or methodologies, and guides students when they experience idea blocks. From a TAM perspective (Davis, 1989), high PU suggests that GenAI is perceived as a performance-enhancing tool. Technologies perceived to improve user performance typically see higher adoption and long-term usage intentions—this is reflected in the relatively high Future Intention scores.

Perceived Ease of Use (PEOU)

Based on the questionnaire results, the perceived ease of use of generative AI is shown in Fig 5. These results are based on 5 questions about perceived ease of use that were given, and we obtained a mean of 3.64, with the highest mean on Generative AI being easy to learn and use (4,11).

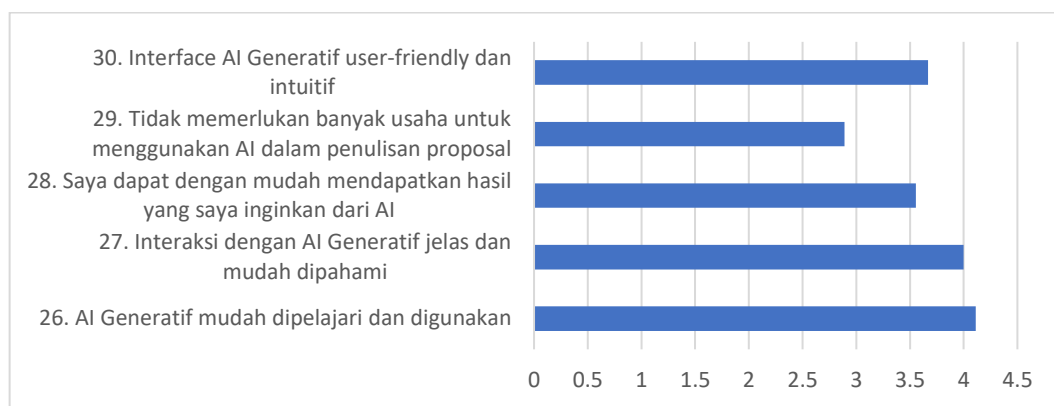


Figure 5. Perceived Ease of Use of Generative AI

Students considered GenAI easy to use due to intuitive interfaces, responsiveness to natural language, lack of specialized technical requirements, ability to follow stepwise instructions, and 24/7 availability. Increased PEOU reduces cognitive load associated with task execution, potentially allowing students to focus more on understanding scientific content rather than the technicalities of writing.

Collaboration Quality (CQ)

Based on the questionnaire results, the collaboration quality of generative AI is shown in Fig 6. These results are based on 5 questions about perceived ease of use that were given, and we obtained a mean of 3.47, with the highest mean on Generative AI drives my creativity in writing proposals (3.77).

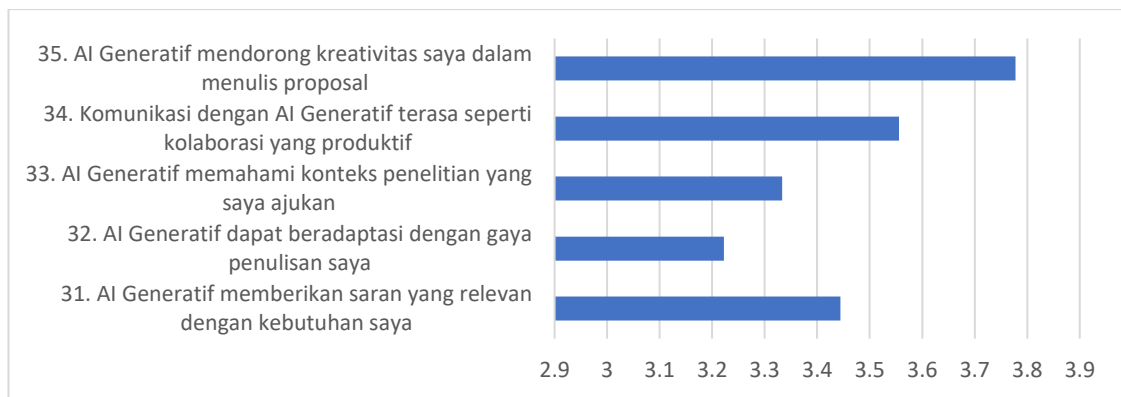


Figure 6. Collaboration Quality of Generative AI

This dimension assesses AI's role as a collaborative partner. Students reported that AI provides relevant suggestions, helps develop ideas, adapts to context changes, structures writing, and effectively improves writing style. However, important limitations were noted: AI often provides generic answers, may not fully grasp local research contexts, and struggles to incorporate real empirical data. Collaboration quality reflects co-agency between humans and AI, consistent with augmented intelligence concepts emphasizing symbiotic partnerships.

Academic Integrity Concerns (AIC)

Based on the questionnaire results, academic integrity concerns of generative AI are shown in Fig 7. These results are based on 5 questions about perceived ease of use that were given, and we obtained a mean of 3.91, with the highest mean on concerns that using AI is considered plagiarism and relying too much on AI, which will reduce students' writing skills (both 4.33).

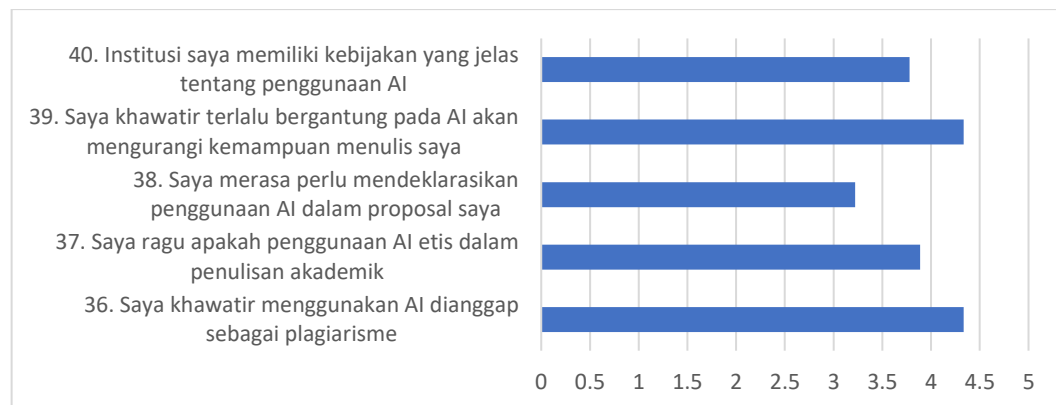


Figure 7. Academic Integrity Concerns of Generative AI

This dimension scored the highest. Students expressed strong concerns about plagiarism risks, uncertainty about permitted AI use, lack of procedures for declaring AI usage, producing work that may not be considered "their own," AI hallucinations, and potential scientific errors. This aligns with UNESCO (2023) warnings about GenAI threats to originality and knowledge integrity.

Learning and Skill Development (LSD)

Based on the questionnaire results, the Learning & Skill Development of generative AI is shown in Fig 8. These results are based on 5 questions about perceived ease of use that were given, and we obtained a mean of 3.62, with the highest mean on AI helping students in developing research skills (3.88).



Figure 8. Learning & Skill Development of Generative AI

Students stated that GenAI helps them understand proposal structure, craft a solid background, differentiate between problem statements and research objectives, summarize literature, and improve grammar and academic style. Some students noted that evaluating AI outputs made them more metacognitive, since they had to verify AI suggestions, rephrase content for context, and compare outputs to primary literature. This supports findings by Holmes et al. (2022) that AI can strengthen learning when used as scaffolding.

Challenges & Barriers (CB)

Based on the questionnaire results, Challenges & Barriers of generative AI are shown in Fig 9. These results are based on 7 questions about perceived ease of use that were given, and we obtained a mean of 3.75, with the highest mean on premium AI subscription fees being too expensive (4.22).

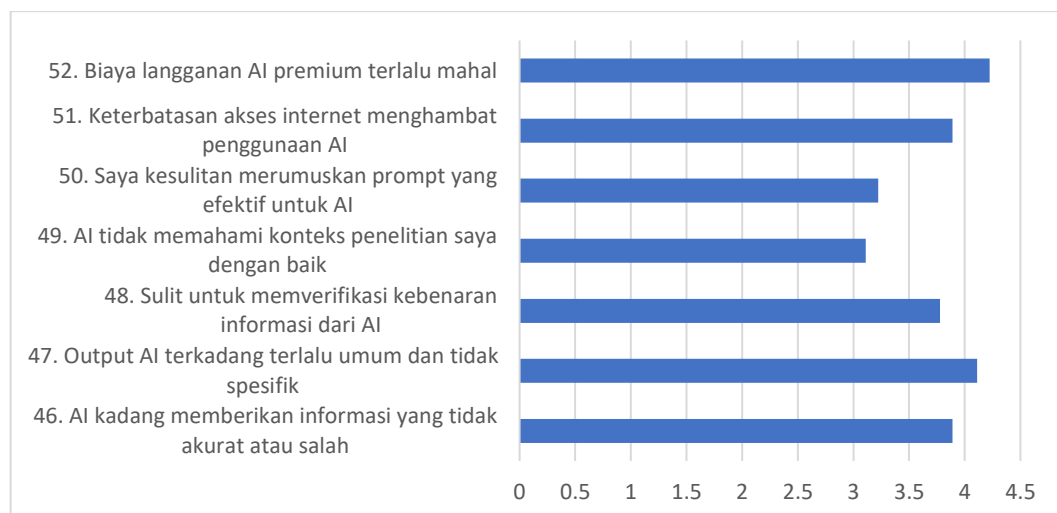


Figure 9. Challenges & Barriers of Generative AI

Students faced several obstacles as follows.

1. Technical: AI hallucinations, overly generic outputs, difficulty producing effective prompts, language and contextual bias, limited internet access, and subscription costs.
2. Epistemic: difficulty verifying sources, AI responses lacking reliable references, and inconsistent accuracy.
3. Ethical: uncertainty about AI usage boundaries, confusion over plagiarism, and fear of being accused of academic dishonesty by instructors.

High scores in this dimension indicate that AI adoption is not without conflict and requires mature digital literacy.

Future Intention to Use (INT)

Based on the questionnaire results, the collaboration quality of generative AI is shown in Fig 10. These results are based on 5 questions about perceived ease of use that were given, and we obtained a mean of 3.71, with the highest mean on students' desire to learn more about how to use AI effectively and students' expectations for the Institution to provide training on using AI (both 4.33).

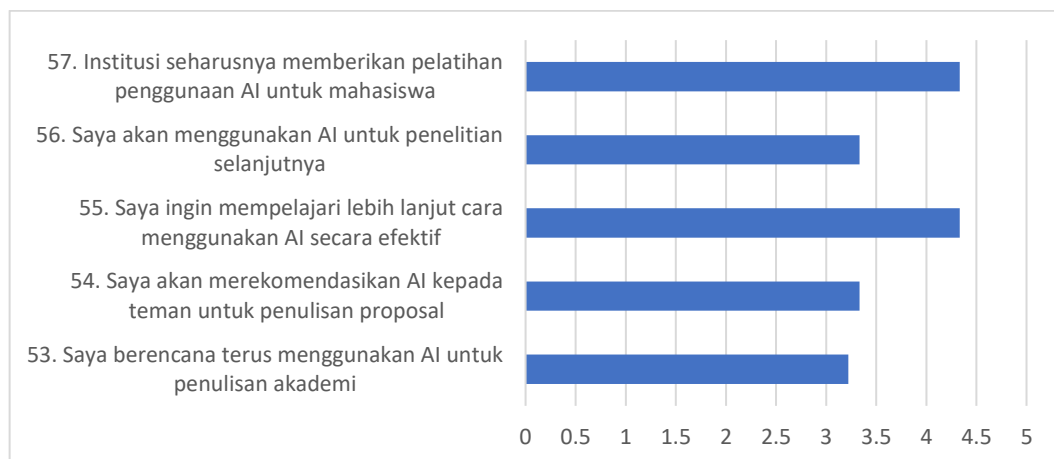


Figure 10. Future Intention to Use of Generative AI

Students intend to continue using AI, provided that there are institutional ethical guidelines, instruction in proper usage strategies, and that use does not breach academic rules. High INT suggests AI is being integrated into the modern academic ecosystem.

Thematic Discussion from Open-Ended Responses

Qualitative analysis of open responses produced three major themes.

Benefits of Generative AI

Based on students' response, students reported benefits including:

1. Faster ideation: AI helps map variables, propose alternative topics, and identify research gaps.
2. Easier background drafting: AI provides exemplar argumentative structures.
3. Language and academic style improvement: AI effectively corrects grammar and enhances coherence.

4. Reduced psychological barriers: AI alleviates writer's block and writing anxiety.
5. Faster revision cycles: AI suggestions help students improve drafts more rapidly.

Challenges in Using GenAI

Based on students' responses, they reported the challenges include:

1. AI hallucinations: seemingly convincing but factually incorrect answers.
2. Limited understanding of local context: AI has difficulty grasping Indonesia-specific situations or empirical realities.
3. Overreliance: fear that students may lose independent writing skills.
4. Unclear originality assurance: AI cannot transparently document its generation process.
5. Prompt engineering difficulty: outputs heavily depend on prompt quality.

Student Recommendations

Based on the responses from the questionnaire, students recommended that there should be official guidelines from the university regarding the use of AI, a statement on the use of AI as an ethical responsibility, training on AI literacy and its proper use, lecturers should be familiar with AI to supervise effectively, and AI should only be used as an aid, not a substitute for students' critical thinking.

Conclusion

This study examined how students utilize Generative AI (GenAI) as both an assistant and a co-creator in the research proposal writing process. Integrating quantitative and qualitative analyses provided a deep understanding of GenAI usage patterns, student perceptions of benefits and ease of use, ethical issues, and epistemological dynamics within higher education contexts.

Overall, GenAI has become a significant component of students' academic writing ecosystems. Students use AI not only for technical tasks like grammar correction and paragraph structuring but also for higher-order cognitive activities such as brainstorming research ideas, drafting backgrounds, formulating research questions, and understanding methodologies. GenAI thus acts as a cognitive amplifier, extending students' intellectual capacities and aiding in knowledge construction. However, effective and ethical use depends on critical, guided, and transparent implementation.

While this study offers preliminary insights, several limitations highlight the need for further investigation. The current data, limited by its scope, suggests that future work must prioritize expanded sample sizes and institutional diversity to validate these initial trends. Furthermore, current literature often relies on cross-sectional data; to truly understand the pedagogical implications, we need longitudinal research that observes the evolution of academic skills, alongside comparative studies distinguishing between users and non-users. Lastly, the practical solution to these challenges—education—remains under-researched; future inquiries should rigorously evaluate the effectiveness of AI-literacy interventions to determine best practices for integration.

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UNDERSTANDING ANAK DALAM TRIBE STUDENTS' EXPERIENCES WITH DEEP LEARNING-BASED AI-GENERATED VOICE CLONING OF *TUMENGGUNG*

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Received: 31 October 2025; Accepted: 8 January 2026

Abstract

Education for *Suku Anak Dalam* has always represented an encounter between two worlds of knowledge about the modern logic of schooling and the oral wisdom sustained by the spiritual authority of the *Tumenggung*. This study explores that question by integrating AI-generated voice cloning of the Tumenggung's voice into a deep learning-based approach. Drawing on a qualitative approach framed by third-generation Cultural-Historical Activity Theory, we examine how this digital artifact mediates the relationships among teachers, students, and indigenous values. The findings reveal that the Tumenggung's digital voice is not merely a replica, but a cultural dialogue space that rekindles a sense of belonging, fosters affective engagement, and builds epistemic bridges between culture and technology. Ultimately, the study suggests that the essence of educational innovation does not lie in machines that imitate humans, but in humans who rediscover their humanity through technology.

Keywords: AI-EdTech, AI-generated voice cloning, Anak Dalam Tribe, cultural-historical activity theory, deep learning

Introduction

The rapid expansion of AI-generated voice cloning, intelligent tutoring systems, and various forms of AI-EdTech has opened new horizons in teaching and learning, expanding the boundaries of time, space, and human learning experience (Allam et al., 2023; Hamal et al., 2022; Jurcys et al., 2024; Kritandani et al., 2024). Yet, behind this advancement lies an enduring question about how technologies built upon modern rationality interact with educational realities rooted in diverse social and cultural ecosystems (Kamalov et al., 2025; Korteling et al., 2021; Michels, 2024). A fundamental concern, therefore, arises: how can AI serve as a means of empowerment for communities that sustain knowledge through local wisdom, rather than becoming a new instrument?

One of the most tangible representations of this dilemma can be found in the educational realities of indigenous communities, including the Anak Dalam Tribe in Jambi, Indonesia. This community maintains a system of values and social structures deeply rooted in spiritual traditions and the charismatic leadership of the



Tumenggung (Rizky & Rahman, 2023; Samsu et al., 2022). Formal education often encounters what can be described as an epistemic wall, a resistance that stems from the incompatibility between the instructional approaches of modern schooling and the cultural logic of indigenous communities (da Silva et al., 2023; Hidayat et al., 2013; Somekh & Nissen, 2011). Many attempts to integrate modern pedagogy into these cultural spaces have failed because they originate from top-down paradigms that marginalize local knowledge authorities (Bone, 2023; Hite et al., 2025). For indigenous learners, education is not a matter of accumulating knowledge but a social practice imbued with spiritual meaning and emotional connection to their environment and communal leaders.

The arrival of AI-generated voice cloning introduces both opportunities and new ethical as well as pedagogical questions. If the voice of the Tumenggung, long regarded as a symbol of authority and cultural legitimacy, can be digitally replicated, could this technology serve as a symbolic bridge that reintroduces the voice of culture into the classroom without erasing its original meaning? Or might it instead become an artificial representation that disrupts the spiritual balance of the community? This debate reflects a broader paradox between two major strands of academic discourse that emphasize AI's potential for educational democratization and social inclusion, and another that warns of its cultural and ethical implications (Baris, 2024; González-Docasal & Álvarez, 2023; Wallin & Tunison, 2022). The gap between these perspectives highlights the need for a theoretical approach capable of fostering a dialogical relationship among humans, culture, and technology.

This paradox also mirrors the dissonance between national educational goals that promote deep learning and the realities of cultural inequality in practice. When modern epistemologies confront collective and spiritual systems of value, a new framework is needed that enables an equal dialogue between technology and local wisdom (Gu, 2021; Harris et al., 2013; Naseer et al., 2024). From this context emerges the idea of bringing the voice of the Tumenggung, the indigenous leader and source of epistemic authority, into learning through AI-generated voice cloning. The presence of the Tumenggung's digital voice represents more than technological innovation; it is an act of recontextualizing deep learning that emphasizes emotional engagement, social relations, and cultural meaning within the learning process (Ali et al., 2025; Gong, 2023; Riomalen et al., 2025; Yuan & Chunrong, 2022).

Some argue that AI can strengthen deep learning by enabling adaptive, personalized, and multisensory learning experiences (Aridan et al., 2025; Naseer et al., 2024). Others are more critical, viewing the trend as a potential source of dehumanization since technology tends to replace rather than enrich the social interactions that are central to meaningful learning (Banh & Strobel, 2023; Bulathwela et al., 2024; Manik et al., 2025). This raises a crucial question: can AI act as a mediating tool that helps students reach a deeper understanding, or does it risk creating a barrier between humans and the humanistic values inherent in learning?

Cultural-Historical Activity Theory (CHAT) provides a conceptual foundation to unpack this complexity. Rooted in Vygotskian thought and expanded by Engeström, CHAT conceptualizes learning as a socially mediated activity shaped by cultural artifacts within specific historical contexts (Clarà, 2015; Cong-

Lem, 2022). Within this framework, technology is not a neutral entity but an integral part of human activity systems that embody values, norms, and power relations. CHAT allows researchers to analyze how AI-generated voice cloning functions as a mediating artifact that connects students, teachers, the Tumenggung, and the indigenous community in a dynamic learning system. From this perspective, technology is not simply a learning aid but a space where cultural values and modernity negotiate and co-construct meaning.

Previous research on AI integration in education (Abulibdeh et al., 2024; Ho, 2025; Kalantzis & Cope, 2024; Perkins, 2023; Tripathi & Yadav, 2025) has largely focused on technological efficiency and cognitive enhancement, while offering little insight into more subtle socio-cultural dimensions such as symbolic authority, emotional experience, and spirituality within indigenous learning environments. Conversely, studies on indigenous education (Bone, 2023; Mangione et al, 2024; Hite et al., 2025; Kovach, 2013; Wallin & Tunison, 2022) rarely consider AI as a productive site of cultural negotiation. It is within this conceptual gap that our study is situated. We aim to understand how AI-generated voice cloning of the Tumenggung mediates literacy learning among Anak Dalam students and how this process shapes their cognitive, affective, and identity-based engagement.

We believe that the success of technology-based education in indigenous education is not determined by algorithmic sophistication but by the extent to which technology can engage in dialogue with the living values of local wisdom. The integration of the Tumenggung's AI-generated voice is not merely a technological innovation but a reflection of humanity's search for meaning in the digital age. It represents an attempt to position technology not as a substitute for human presence but as a means to strengthen the relationship between people, culture, and knowledge. Grounded in the framework of Cultural-Historical Activity Theory, this study seeks to explore how deep learning-based AI-generated voice cloning can become a learning medium that is not only technologically intelligent but also culturally sensitive and pedagogically humanistic.

Method

This research adopted a qualitative case study design framed by Cultural-Historical Activity Theory (CHAT). We selected this approach not only for its theoretical fit but for its ability to view learning as a social activity where every action, symbol, and mediating tool reflects the community's living history and cultural values (Batiibwe, 2019; Sumbera, 2021). The methodology rests on an epistemic awareness that knowledge grows from specific social contexts rather than from a position of neutrality.

This study took place in a public elementary school located near the Anak Dalam Tribe community in Jambi Province. We explored how students engaged with AI-generated voice cloning and how they experienced the Tumenggung's voice as part of learning. For these children, hearing the Tumenggung's voice was not only an educational moment but also a symbolic encounter with the authority of knowledge, where technology mediated the dialogue between tradition and modernity. Participants included 18 students from grades II–VI, two teachers, and the Tumenggung as the key epistemic figure. Participants were purposively selected for their potential to provide rich insights into the learning process. Data were gathered through in-depth interviews, participatory observation, and document

analysis. The interviews focused on students' affective experiences about how they interpreted the digital voice and how it influenced their engagement with literacy. Observations examined classroom dynamics, interaction patterns, and shifts in atmosphere when technology entered as a mediating tool.

Data analysis followed an iterative, dialogical process informed by Miles and Huberman's principles of data reduction, display, and verification (Qomaruddin & Sa'diyah, 2024). Within the CHAT framework, analysis mapped the activity system by identifying subjects, mediating tools, cultural values, and community interpretations of change. Each piece of data was treated as both a representation and a cultural trace, reflecting social and historical meanings embedded in learning. Credibility was strengthened through member checking with teachers and the Tumenggung. This process unfolded as a reflective conversation rather than a formal validation, enabling us to refine interpretations collaboratively. Ethical protocols followed local customs, oral consent was obtained, the digital voice was symbolically approved by the Tumenggung, and all documentation was returned to the community as reciprocal practice.

Throughout the study, we positioned ourselves as part of the learning ecology rather than detached observers. Field reflection became integral to analysis as we, too, were shaped by the experience of hearing the Tumenggung's digital voice and witnessing students' reverence and curiosity. In this sense, methodology evolved into a form of human engagement connecting researcher, technology, and culture.

Ultimately, this research design does not prescribe rigid procedures but seeks to articulate how inquiry can become a dialogue between local wisdom and technological innovation. Studying deep learning-based AI-generated voice cloning within indigenous education is, at its core, a study of humanity of how learning, voice, and meaning are continuously redefined in an increasingly algorithmic world.

Findings and Discussion

The findings were mapped using the third-generation Cultural-Historical Activity Theory (CHAT) framework, which enabled an analysis of interactions between two activity systems: the formal education system and the indigenous cultural system. Within this framework, the integration of AI-generated voice cloning of the Tumenggung's voice served as a mediating artifact bridging both systems and creating a shared object literacy learning that is cognitively, affectively, and culturally meaningful. (Cong-Lem, 2022; Grimalt-Álvaro & Ametller, 2021; Somekh & Nissen, 2011).

Field observations revealed that learning among Anak Dalam students was shaped not only by the pedagogical relationship between teacher and learner but also by the symbolic intervention of the Tumenggung's digital voice, which carried epistemic and spiritual authority. The AI voice thus operated in dual roles, as a modern learning technology that facilitated deep learning and as a cultural representation reinforcing identity and belonging.

Table 1. Mapping of Dual Activity Systems through the Third-Generation CHAT Framework

Element	Formal Education System	Indigenous Cultural System	Interaction / Shared Object
Subject	Teachers and students participating in literacy learning with technology	Tumenggung and community members as sources of cultural authority	Students as boundary agents navigating two epistemic worlds and forming hybrid learning identities
Object	Literacy development through AI-EdTech and deep learning	Transmission of local values, narratives, and wisdom	Transformation of literacy into a culturally grounded learning practice
Tools (Artifacts)	AI-generated voice cloning, audiovisual media, and interactive texts	Oral tradition, native language, spiritual symbols, communal rituals	Tumenggung's digital voice as a cross-cultural mediating artifact connecting technology and spirituality
Rules	National curriculum, school policy, digital ethics, and learning schedules	Customary norms, spiritual taboos, social order, and traditional communication	Negotiation of ethics and legitimacy between digital and spiritual orders
Community	Teachers, students, principals, technology developers, and educational institutions	Indigenous community, cultural leaders, students' families, spiritual elders	Collaborative cross-cultural learning community grounded in mutual recognition
Division of Labour	Teachers as facilitators and mediators, students as active learners	Tumenggung as meaning source, community as value custodian	Redistribution of knowledge authority toward epistemic partnership
Outcome	Enhanced literacy, active participation, and openness to technology	Strengthened cultural identity and community pride	Deep learning that integrates cognitive, affective, and cultural dimensions reflectively and transformatively

Empirically, the integration of AI-generated voice cloning transformed students' learning structures. Students displayed heightened engagement, enthusiasm, and reflective depth when listening to the digital voice of the Tumenggung. The voice was perceived not only as a learning medium but as a symbolic presence legitimizing school-based activities within a cultural frame. This created a boundary zone between modern schooling and indigenous epistemology, a shared space where knowledge was collaboratively produced across cultural borders.

The findings affirm that success in integrating technology within indigenous education is not defined by technical sophistication but by the technology's ability to act as social and cultural mediation. Through the Tumenggung's AI voice, the two systems—formal and indigenous- are intertwined to form a reflective and transformative learning practice grounded in living human values.

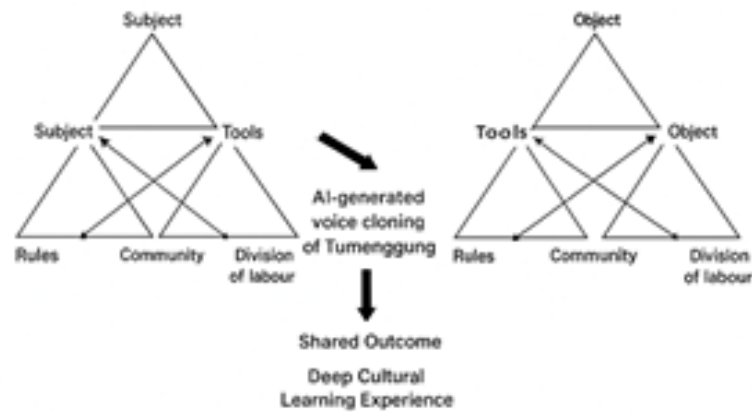


Figure 1. Representation of Interacting Activity Systems

The Tumenggung's digital voice functioned not merely as an instructional tool but as a cultural artifact representing the intersection of technology and tradition. For the Anak Dalam community, voice is not only a medium of communication but a vessel of value, knowledge, and spirituality. When replicated through AI, it reconfigured the epistemic space where embodied authority is represented in digital form, yet still retains symbolic and spiritual power.

These findings align with Agrawal (2023) and Gidiotis & Hrastinski (2024) who argue that artificial intelligence always intertwines with the social values that shape its use. The Tumenggung's voice extends the notion of mediation, showing that no learning artifact is neutral, as each carries embedded values, norms, and power relations (Ross et al., 2022). The cloned voice thus emerges as a negotiated space where cultural identity and digital modernity meet to construct new understandings of learning.

Students' encounters with the AI-generated voice elicited strong emotional responses. Many described the experience as if the Tumenggung were physically present, a symbolic form of presence that fostered emotional closeness and deepened engagement. This reinforces prior studies (Ho, 2025; Qin et al., 2022; Schneider et al., 2022) which highlight how emotional presence in digital learning enhances engagement and comprehension. A familiar and respected voice created intimacy in the classroom, transforming technology into a bridge that revived collective values in modern learning spaces.

At the same time, epistemic tension emerged. Some teachers and community members questioned the authenticity of a replicated voice and its right to represent the Tumenggung's original authority. This raised critical issues of authenticity and representation often overlooked in technology-driven education. Ejjami (2024) warns that modern biases in AI risk positioning algorithms as new sources of truth. Yet, in this study, such tension proved productive but encouraged reflection and dialogue about presence, authority, and meaning in learning.

The digital voice of the Tumenggung reveals that the value of innovation lies not in how precisely technology imitates humanity, but in how it sustains dialogue where cultural values continue to breathe amid digital change. This research expands the CHAT framework by showing that mediating artifacts can be material, social, emotional, and spiritual. Learning mediated by the Tumenggung's AI voice

demonstrates that technology can serve as a connector between tradition and renewal, a means of preserving cultural continuity through learning grounded in reflection, reverence, and shared humanity.

Multi-Voicedness and Negotiation of Meaning Across Activities

The integration of the Tumenggung's AI-generated voice created a dynamic interaction among three main activity systems: teachers, students, and the indigenous community. These systems did not operate linearly but influenced one another in constructing new understandings of learning. This phenomenon reflects the principle of multi-voicedness, where each system brings distinct goals and values while striving toward a shared outcome. Within the Anak Dalam learning space, the coexistence of these voices produced not conflict but a new harmony rooted in ongoing negotiation between local wisdom and technological innovation.

Teachers viewed the AI voice as a pedagogical bridge connecting school and community. For students, it reintroduced a familiar and respected figure, strengthening emotional engagement and cultural belonging. Meanwhile, the community responded ambivalently about appreciating the recognition of their culture within schooling, yet was concerned about the potential dilution of spiritual meaning through digital replication. This tension formed a discursive arena where authority, authenticity, and knowledge were continuously redefined.

As Murtaqiatusholihat et al. (2023) emphasizes, authentic learning arises from dialogue among multiple value systems rather than dominance by one. The intersection between indigenous epistemology and technological logic demonstrated that actors within the Anak Dalam education context were able to create a reflective and adaptive learning community. This resonates with Selasih & Sudarsana (2018) who found that successful technology integration depends on a society's ability to renegotiate meaning while remaining culturally grounded.

The phenomenon of multi-voicedness also challenges the traditional notion of the teacher as the central authority. Within this expanded system, authority becomes distributed; the teacher mediates learning, the digital Tumenggung provides cultural legitimacy, and students interpret experience through their own understanding. This process illustrates expansive learning, in which knowledge emerges through cross-role collaboration rather than one-way transfer (Guberman et al., 2021; Guberman & Smith, 2021).

Ultimately, the presence of the AI-generated Tumenggung demonstrates that technology can broaden participation in indigenous education without eroding collective identity. The negotiation among these actors signals not fragmentation but transformation as an evolution toward dialogic and inclusive learning. The AI voice thus becomes a living site of negotiation where local values, modern pedagogy, and digital knowledge intersect to create renewed meanings of learning. It models a form of education that transcends the binary between tradition and modernity, showing that amid epistemic tension, technology can nurture dialogue and enrich human understanding.

Transformation of the Subject and Expansion of the Learning Zone

This study reveals that the Tumenggung's digital voice shifted learners from passive recipients to active participants engaged in reflection and meaning-making. Students no longer merely listened; instead, they negotiated the meanings of a voice

they recognized and respected. This shift reflects the central principle of third-generation CHAT, where the subject transforms through interaction with mediating tools and social communities (Grimalt-Álvaro & Ametller, 2021). AI here functions not only as a technological aid but as a medium for new awareness, guiding students to connect identity, culture, and knowledge.

The AI-generated voice created a reflective space where students experienced cultural values personally and emotionally. Learning became deeper as it moved beyond formal instruction toward symbolic engagement that evoked a sense of ownership of knowledge based concept of deep learning, where understanding emerges when new information connects with one's lived values and experiences (Andayanie et al., 2025; Riomalen et al., 2025).

This transformation also reshaped the roles of teachers and the community. Teachers repositioned themselves as facilitators navigating between modern and local epistemologies. They learned how technology could revive hidden cultural meanings within formal education. Meanwhile, the indigenous community found new ways to preserve their heritage through symbolic integration into school learning. The digital voice of the Tumenggung became an intergenerational bridge, sustaining tradition while embracing change.

Through this integration, learning among Anak Dalam students evolved into a space where technology and local values enrich one another. AI reintroduced spiritual and social experiences once accessible only through the direct presence of the Tumenggung. In this sense, students learned not only academic content but also to rediscover their cultural roots and sense of identity. This represents the essence of deep learning, where knowledge is not only understood but also lived and shared.

Contradictions, Tensions, and Transformation of the Activity System

The integration of the Tumenggung's AI-generated voice unfolded not as a linear process but through a series of contradictions and tensions that reshaped the entire learning system. These tensions emerged across layers between spiritual values and technological rationality, between traditional authority and formal schooling, and between community expectations and modern pedagogical standards (Kovach, 2013; Shaikh & Hossen, 2025). Rather than obstacles, such contradictions became catalysts for transformation, illustrating that growth within an activity system arises through the effort to resolve internal conflicts.

Teachers and students played key roles in bridging differences between cultural and technological logics. Teachers who once acted as controllers of learning were challenged to engage with the emotional and spiritual dimensions evoked by the Tumenggung's digital presence. They faced epistemological dilemmas in balancing cultural authenticity and pedagogical goals, yet gradually discovered that the AI voice fostered emotional closeness and engagement otherwise difficult to achieve.

Within the indigenous community, tension centered on the authenticity of representation. Some feared that reproducing the Tumenggung's voice might diminish its sacredness, while others regarded it as a respectful way to preserve heritage in digital form. Such debates affirm that cultural adaptation to technology is never neutral; it involves negotiation of meaning and power. Through sustained dialogue, the community came to view AI not as a threat but as a means to ensure that indigenous values remain vital within modern education. Students, meanwhile,

moved from initial ambivalence between awe and unease to perceiving the digital voice as a symbolic presence that enabled deeper reflection. The idea of contradictory expansion, where internal conflict produces new understanding and extends the learning horizon.

From a broader systemic view, tension among subjects, tools, and the community generated expansive transformation. Teachers, students, and community members collaboratively redefined education as a practice grounded in cultural values yet open to renewal. Contradiction, therefore, is not a symptom of failure but a sign of evolution toward higher awareness and complexity. The sustainability of AI-based education in indigenous contexts depends less on technical efficiency than on the social system's ability to adapt and reflect. Tension must be embraced as a source of learning energy, for the AI-generated voice ultimately mirrors the ongoing dialogue between humanity, culture, and knowledge, reminding us that authentic education grows from the meeting of the sacred and the digital, the inherited and the reimagined.

Expansive Learning Cycle and Reconfiguration of Pedagogical Practice

The integration of the Tumenggung's digital voice within the Anak Dalam learning process unfolded as a journey of shared reflection. The expansive learning cycle, where transformation grows from tension and dialogue rather than from linear progress. The first spark came from the meeting of two epistemic worlds: the sacred oral tradition and its digital reproduction. This moment of contradiction urged teachers, students, and community members to pause, question, and rediscover what it truly means to learn together. Through this collective reflection, they began shaping new ways of teaching and learning that honored both technological possibility and cultural meaning.

At first, teachers saw the AI voice merely as a tool to make lessons more engaging. Over time, however, they realized that the presence of the Tumenggung's voice was not simply functional but challenged their old assumptions about knowledge and authority. Teaching became less about transferring content and more about building understanding through shared dialogue. The community, too, found its voice in this process. Through discussion and participation, they reimagined the sacred, recognizing that technology could help preserve their wisdom without hollowing its spiritual depth. In this way, learning extended beyond the classroom, forming a living network that connected teachers, students, technology, and culture.

For students, this journey was deeply personal. Listening to the Tumenggung's AI voice invited them to see learning as part of who they are, not just what they do. They experienced what Rulyansah et al. (2025) and Hutapea et al. (2024) describes as transformative engagement, where understanding touches identity and emotion as much as cognition. Reading and writing became acts of remembering and belonging. From this experience grew a new kind of pedagogy that uses AI not to replace human presence, but to spark conversation and care. Teachers began drawing on cultural narratives, the community contributed stories and voices, and students learned to connect knowledge with life. In this ecology of learning, technology and tradition no longer stand apart; they breathe together, renewing both education and the meanings that hold it alive.

Implications for CHAT and Indigenous Education

Within the framework of CHAT, the integration of the Tumenggung's AI-generated voice should be viewed not simply as the use of a digital artifact but as the creation of a new activity system that mediates relationships among subjects, communities, and cultural values. This process illustrates how technology can act as a cultural mediator that brings spiritual and social meaning into contemporary learning contexts while maintaining the integrity of traditional authority. Rather than functioning as an external or neutral tool, the technology becomes part of a living dialogue between knowledge, culture, and human experience.

From a theoretical perspective, this study expands the scope of CHAT beyond its traditional applications in school and workplace settings by positioning indigenous education as a distinctive epistemic domain. Third-generation CHAT emphasizes the importance of dialogue between intersecting systems of activity. In this research, the modern school and the indigenous community interact through the mediation of AI, producing a hybrid form of learning that challenges the long-standing separation between modernity and tradition. These findings suggest that activity theory should also account for how technological tools participate in the negotiation of values and meaning within cultural systems.

From an epistemological standpoint, the findings demonstrate that knowledge is not produced by a single, autonomous source, but emerges through reflective interactions among people, artifacts, and the social world in which they are embedded. The presence of the Tumenggung's digital voice disrupts the conventional boundary between indigenous and modern epistemologies, giving rise to epistemic hybridity. In this space of convergence, students develop not only literacy skills but also an awareness that learning is a social act connected to their cultural and emotional identities. The findings, therefore, highlight that AI can serve as a medium through which learners experience and reinterpret their heritage in meaningful ways.

Conceptually, this study contributes to the development of a decolonial approach to AI pedagogy by illustrating how technology can strengthen rather than replace local ways of knowing. When students from the Suku Anak Dalam learn through the familiar voice and symbols of their own culture, technology becomes a means of cultural affirmation and empowerment. The study thus reinforces the view that meaningful integration of AI in education depends not on algorithmic sophistication but on the capacity of technology to resonate with human values and communal life. A culturally responsive CHAT perspective shows that when used ethically and reflectively, technology can connect modern learning with the wisdom of tradition, offering new possibilities for education that remain grounded in humanity.

Conclusion

This study affirms that the integration of deep learning-based AI-generated voice cloning of the Tumenggung into the learning process of Anak Dalam students represents not merely a technological innovation but an epistemic dialogue between modernity and indigenous wisdom. Through the lens of CHAT Theory, we found that the Tumenggung's digital voice serves as a mediating artifact that connects cognitive, affective, and cultural dimensions within a dynamic system of learning activity. This process creates a learning space that not only enhances students'

engagement and intrinsic motivation but also restores cultural authority within the formal education system, which has often marginalized local values. Practically, the findings suggest that the success of technology-based education in indigenous education depends less on algorithmic sophistication and more on the technology's ability to resonate with the value systems and social relations that sustain the community. Theoretically, this research expands the horizon of CHAT by situating indigenous education as a new epistemic domain that challenges the long-standing dichotomy between humans, culture, and machines. Furthermore, the ethical and sustainability dimensions of using AI voice cloning in educational spaces warrant further inquiry, particularly concerning cultural autonomy and the potential commodification of vocal identity.

Future research could extend this work by exploring cross-community comparisons, examining the negotiation of meaning between human and non-human actors, and developing more participatory models of AI-human collaborative pedagogy that remain sensitive to cultural contexts. In conclusion, this research should not be seen merely as an experiment in technological integration but as an effort to cultivate new awareness that education in the age of artificial intelligence demands a balance between innovation and wisdom. The AI-generated voice of the Tumenggung is not a symbol of dehumanization but an entry point into a renewed form of dialogue among humans, culture, and technology in the shared pursuit of meaningful learning.

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DIGITAL CLASSROOM CATECHESIS FOR BETA LEARNERS IN THE ERA OF ARTIFICIAL INTELLIGENCE

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Received: 16 December 2025; Accepted: 13 January 2026

Abstract

This article examines the design of digital catechesis for Generation Beta learners in the era of Artificial Intelligence (AI). There is a critical research gap between AI-shaped learning environments and existing catechetical models, which often remain informational, technocratic, or influenced by dogmatic scientism. Drawing on Barna Institute data (on Gen Z as the spiritual precursor) and McCrindle's generational framework (Gen Beta as the first cohort formed within ambient AI), the study establishes the learners' context. Integrating Yuval Noah Harari's data-centric analysis with Pope Francis's theology on digital culture, an interdisciplinary theoretical framework is developed. The Research Question is: How can digital catechesis for Generation Beta resist dogmatic scientism while remaining faithful to the kerygmatic, relational, aesthetic, and mystical dimensions of Christian formation? Utilizing a qualitative conceptual methodology integrating theoretical analysis and constructive theological reflection, the Research Findings indicate that approaches centered on narrative encounter, relational accompaniment, aesthetic mediation, and ethical discernment are more effective than content-driven models. The article's Novelty lies in reimagining digital catechesis as a theologically intentional formative ecology that critically integrates AI while safeguarding the integrity of Christian kerygma and spiritual depth.

Keywords: artificial intelligence, digital catechesis, dogmatic scientism, generation beta, Kerygma

Introduction

This study emerges from the author's sustained pedagogical engagement with Generation Alpha learners in formal Catholic Religious Education (CRE) classrooms. Through daily practices of teaching, accompaniment, and reflective observation, a persistent tension has become increasingly evident. While young learners are formed within environments marked by digital immediacy, multimodal communication, and algorithmic mediation, classroom catechesis often remains linear, text-centered, and propositional. Dominant pedagogical routines continue to privilege explanation and cognitive recall over relational encounter, affective engagement, and experiential meaning-making. What initially appeared as a localized classroom difficulty gradually revealed itself as a systemic pattern, pointing to a deeper misalignment between inherited catechetical models and the epistemological conditions shaping digitally formed learners.

This misalignment can be more precisely identified as a form of *dogmatic scientism* embedded within catechetical practice. Grounded in a reductionist



epistemology, this approach construes theological truth primarily as cognitively transmissible, empirically verifiable, and assessable propositions. As a result, doctrinal precision is privileged at the expense of narrative imagination, aesthetic mediation, affective resonance, and interpersonal encounter. While research in digital religion, generational learning, and AI ethics addresses related concerns, these fields largely operate in parallel and stop short of offering an integrated pedagogical design. Consequently, catechesis remains conceptually coherent yet spiritually attenuated, particularly for learners whose meaning-making is relational, visual, and experiential. This unresolved tension constitutes the central research gap addressed in this study.

The limitations of prevailing catechetical models become more pronounced when viewed through the pastoral vision of Pope Francis. In documents such as *Evangelii Gaudium* and *Christus Vivit*, Pope Francis (2013, 2019) consistently resists technocratic rigidity, calling the Church toward evangelization grounded in encounter, beauty, and the primacy of the kerygma. This vision contrasts sharply with catechetical practices centered on abstraction and systematization. Parallel insights from Campbell (2013), Campbell and Dyrness (2016), and Helland (2016) demonstrate how digital cultures reshape authority and religious meaning-making. The urgency of this critique is intensified by the emergence of Generation Beta, whose formation will unfold within AI-mediated environments (McCrindle & Wolfinger, 2014; McCrindle et al., 2023; McCrindle, 2025). Together, these developments reveal a widening pastoral and epistemological gap.

Building upon the earlier diagnosis of epistemological misalignment in contemporary catechesis, this failure to reconcile pastoral vision with digital culture constitutes the core theoretical and practical research gap addressed in this study. Drawing on Campbell's (2012) concept of *Digital Religion*, the current situation reflects an unresolved tension between the individualized logic of digital environments and the communal authority of religious tradition. This tension manifests as a subtle form of scientific dogmatism, explicitly critiqued by Mary E. Hess (2019a, 2019b, 2022, 2023), who calls for responsive faith formation grounded in Narrative, Aesthetic, and Digital Paths rather than rigid content transmission. Yet many existing digital catechetical models continue to reproduce the very dogmatism Hess resists by privileging quantifiable performance metrics over relational and spiritual depth. Consequently, no established framework currently integrates advanced AI technologies while remaining faithful to anti-dogmatic, aesthetic, and communal principles of faith formation.

Responding directly to this gap, the novelty of this research lies in the introduction of the Andalus Initiative as a concrete pedagogical intervention. By operationalizing Hess's three pedagogical paths within Campbell's hybrid digital space, the initiative develops a Digital Class Catechesis model specifically designed for Generation Beta. This model deliberately resists dogmatic reductionism and digital individualization by fostering shared narrative meaning, aesthetic engagement, and communal participation. The study's distinctive contribution lies in providing empirical evidence that a visually attuned, non-dogmatic framework can effectively harness AI technologies while safeguarding the communal authority essential to Christian spiritual formation.

More specifically, this study makes three contributions to contemporary discussions on digital catechesis for Generation Beta. First, it critically rearticulates

digital catechesis by naming and resisting dogmatic scientism as an implicit epistemological posture, reframing catechesis as an encounter-oriented and sacramental process within AI-mediated environments. Second, it advances catechetical theory by conceptualizing Generation Beta not merely as digitally fluent learners but as an AI-shaped anthropological category, extending McCrindle's generational analysis through the Andalas pedagogical framework. Third, it proposes an integrative theological–pedagogical model that synthesizes insights from digital religion, AI and religious education, generational pedagogy, and Catholic catechetical theology for concrete classroom practice.

Guided by this synthesis, the study addresses the following research question.

How can digital catechesis for Generation Beta resist dogmatic scientism while remaining faithful to the kerygmatic, relational, aesthetic, and mystical dimensions of Christian formation? In responding to this question, the article offers a theologically grounded and pedagogically viable vision of digital catechesis for Catholic Religious Education teachers across diverse cultural contexts. It integrates cultural critique, generational theory, and catechetical theology to engage the ethical, spiritual, and pedagogical challenges of AI-mediated learning environments. In doing so, digital catechesis is positioned not as a reactive accommodation to technological disruption, but as a faithful, relational, and imaginative mode of ecclesial accompaniment in an AI-shaped world.

Related Studies and Theoretical Framework

Related Studies

This study is situated at the intersection of digital culture, generational formation, and contemporary catechetical theology. As outlined in the Introduction, Beta learners are shaped within educational and social environments increasingly influenced by artificial intelligence, algorithmic mediation, and data-driven systems. These conditions affect not only how learners access and process information but also how they form identity, negotiate authority, and engage religious meaning. Such complexity cannot be adequately addressed through a single disciplinary lens. Accordingly, the following review of related studies maps the scholarly terrain that informs this research. It draws together insights from digital religion, generational studies, educational theory, and catechetical theology. By locating the present study within this intellectual landscape, the review clarifies both its conceptual grounding and its distinctive scholarly contribution.

Yuval Noah Harari's work (2017, 2018, 2024a, 2024b) provides a critical anthropological lens for understanding the digital conditions shaping Generation Beta. Rather than examining isolated technologies, Harari analyzes long-term civilizational patterns affected by artificial intelligence and large-scale data systems. In *Homo Deus* and related writings, he argues that data has acquired unprecedented epistemic and moral authority, a worldview he terms *Dataism*. Within this logic, meaning, value, and decision-making are increasingly governed by algorithmic processes. Those who control data consequently shape behavior, desire, and the future itself. Harari's contribution lies in exposing the ideological atmosphere in which digital catechesis unfolds—one where learners risk internalizing algorithmic authority and reducing meaning to computational metrics rather than relational or transcendent horizons.

Where Harari diagnoses the cultural logic of the data-driven world, McCrindle and Wolfinger (2014) and McCrindle (2025) approach the digital age through generational sociology. His research examines how demographic change, technological acceleration, and global connectivity shape the learning dispositions of emerging cohorts. Through longitudinal and cross-cultural analysis, McCrindle identifies Generation Beta as the most globally connected, technologically immersed, and data-shaped generation to date. He highlights traits such as visual orientation, responsiveness to immediate feedback, and expectations of interactivity and experiential learning. These characteristics are increasingly evident within AI-mediated educational contexts, including Indonesia. McCrindle's work offers essential empirical grounding for understanding how Beta learners process information, form identity, and engage meaning.

A third stream of insight emerges from Pope Francis, whose contribution is grounded in pastoral theology and ecclesial discernment rather than social science. In texts such as *Christus Vivit* and his reflections on digital culture, Francis offers a theological–anthropological reading of how technology shapes attention, identity, and relationships. He acknowledges both the risks of fragmentation, loneliness, and manipulation and the potential of digital spaces for encounter and creativity. Central to his vision is the insistence that human dignity must never be reduced to algorithmic logic. Francis calls educators to cultivate relational presence, discernment, and contemplative depth amid technological acceleration. His contribution re-centers catechesis on personhood, encounter, and the sacredness of human experience under digital pressure.

Taken together, Harari, McCrindle, and Francis illuminate the cultural, generational, and pastoral dimensions necessary for understanding Beta learners in the age of artificial intelligence. Harari exposes the ideological power of data, McCrindle describes the generational formation that occurs within data-driven environments, and Francis articulates a theological response grounded in relationship, embodiment, and hope. Their combined insights reveal both the risks and the possibilities facing catechesis within AI-shaped classrooms. While other scholars contribute important perspectives through research on AI ethics, digital religion, and interactive pedagogy, their work functions primarily as complementary enrichment. The conceptual core of this study is shaped by the triangulation of cultural critique, generational analysis, and pastoral theology offered by these three thinkers.

Andalas (2020, 2025) provides a distinctive, contextually significant contribution by translating global insights into a concrete theological-pedagogical framework for classroom catechesis. Engaging with literature on digital natives and experiential learning, Andalas (2020) argues that catechesis for Generation Alpha must be based on multisensory learning. This approach intentionally integrates visual, auditory, kinesthetic, and affective dimensions to ensure faith is experientially appropriated, not just cognitively transmitted. Drawing on McCrindle's (McCrindle & Wolfinger, 2014; McCrindle et al., 2023) 'app generation' concept, Andalas situates practice within narrative, aesthetic, and interactive learning ecologies. Multisensory learning thus serves as a mediating framework, integrating *via narrativa*, *via pulchritudinis*, and *via digitalis*, positioning digital media as an integral locus of ecclesial encounter.

Building on this foundation, Andalas (2025) advances the discussion by explicitly addressing the implications of artificial intelligence for religious education. He calls for the intentional design of digital classroom catechesis that critically engages digital culture and understands AI as a formative anthropological context rather than a neutral tool. Rejecting instrumentalist approaches, Andalas argues that AI reshapes perception, agency, and relationality, thereby requiring a reconfiguration of catechetical praxis. He reimagines catechesis as a dialogical, narrative, and aesthetically attuned learning space that cultivates discernment, moral imagination, and hope. Within this vision, learners are accompanied as pilgrims of hope, capable of articulating and embodying Catholic faith amid the rapid transformations of a digitally mediated world.

Theoretical Framework

The foundation of this framework is the cultural and anthropological shift brought about by the era of artificial intelligence. Harari's critical insight that "the universe consists of data flows, and the value of any phenomenon is determined by its contribution to data processing" positions AI not merely as a tool but as a formative environment that shapes cognition, attention, and social interaction. Furthermore, his observation that "those who control the data control the future" underscores the need to interpret digital catechesis as a pedagogical space shaped by algorithmic logics, data-driven identity formation, and computational efficiencies. In such a context, knowledge is increasingly measurable, optimized, and filtered through automated systems, presenting both a cultural challenge and a theological invitation: the Church must articulate a vision of the human person as unrepeatable, relational, and dignified in a world that increasingly reads individuals as data points.

McCrindle and Wolfinger (2014), McCrindle et al. (2023), and McCrindle (2025) together provide the theoretical grounding for this article's focus on **digital catechesis for Generation Beta learners in the era of artificial intelligence**. Barna's research on Generation Z reveals a generation that is spiritually receptive yet institutionally cautious, morally subjective yet evidentially minded, and strongly oriented toward authenticity, emotional well-being, and personal meaning. These dispositions are not temporary developmental features but structural cultural patterns that shape the learning ecology inherited by Generation Beta. McCrindle's analysis further identifies Beta learners as the first generation to encounter AI not merely as a tool, but as an ambient condition that subtly forms cognition, authority, and moral imagination. Within such conditions, classroom-based catechesis can no longer be conceptualized as doctrinal delivery detached from digital mediation.

The convergence of Barna (Barna Group & Impact 360 Institute, 2018, 2021, 2024), McCrindle and Wolfinger (2014), McCrindle et al. (2023), and McCrindle (2025) thus reframe the catechetical classroom itself as a digitally situated formative space. For learners shaped by algorithmic personalization, fragmented attention, and experience-driven meaning-making, digital catechesis must attend to both pedagogical form and theological content. The author's proposed model responds to this shift by emphasizing relational presence, narrative integration, and ethical discernment within AI-mediated learning environments. Rather than reproducing dogmatic scientism or reducing faith to informational content, digital catechesis is envisioned as an encounter that forms conscience, imagination, and

relational capacity. In this sense, the digital classroom becomes a locus of accompaniment where faith is learned through guided participation rather than passive reception.

This orientation is especially urgent for Generation Beta, whom McCrindle (2025) describes as “the most globally connected, technologically immersed, and data-shaped generation ever born.” Their learning habits are increasingly structured by recommendation systems, interactive interfaces, and immersive media, reshaping attention, authority, and trust. Consequently, effective digital catechesis for Beta learners must be experiential, dialogical, and critically engaged with AI rather than technologically neutral. Generation Beta is approached not simply as a demographic cohort but as a theological interlocutor whose faith formation unfolds within intelligent systems. Designing catechesis for this context, therefore, requires reimagining the digital classroom as a theologically intentional ecology—one capable of mediating encounter, meaning, and moral formation in the age of artificial intelligence.

In response to these generational and technological realities, classroom catechesis must be reconceived. Pope Francis provides the central theological lens for this transformation. In *Evangelii Gaudium*, he notes that “the digital environment... influences the way people learn and the development of their critical sense,” highlighting the persistence of dogmatic, content-focused teaching in digital contexts. When learners are habituated to treat information as consumable data, catechesis that functions only as doctrinal delivery risks reinforcing the very epistemic logic that needs to be transcended. *Christus Vivit* frames a kerygmatic alternative: “Christianity is not a collection of truths to be believed... Christianity is Christ.” Relational encounter, rather than content transmission, becomes the organizing principle of catechesis, emphasizing affective resonance, personal transformation, and relational wonder.

Mary emerges as a central pedagogical model in this digital and generationally informed framework. Pope Francis describes her as the “influencer of God” and “the greatest of all influencers” (CV 44). In classroom catechesis, Mary embodies influence exercised through authenticity, relational presence, and faithful accompaniment rather than authority or visibility. Reframing her life through digital metaphors—for example, as one who “uploaded” Jesus into the world—enables learners to grasp that influence in the Christian sense involves courage, availability, and participation in God’s mission even amid uncertainty. Mary thus bridges the theological, generational, and digital dimensions of this framework, modeling how relational authenticity can translate into pedagogical practice for Beta learners.

The dynamics of digital classrooms sharpen the tension between teachers as “digital immigrants” and learners as “digital natives,” shaping pedagogy at both practical and epistemological levels. Teachers often employ linear, text-centered methods formed in pre-digital contexts, while learners engage through visuality, interactivity, immediacy, and affective resonance. This mismatch risks reducing catechesis to information transfer rather than encounter. Here, Pope Francis’s vision of catechists as “facilitators of grace” rather than “holders of grace” becomes crucial. Catechists are called not to control meaning but to accompany learners by curating relational and narrative-rich environments. Through attentiveness and ritual sensitivity, catechesis becomes a dialogical space where faith formation meets digitally mediated realities.

Taken together, these insights reframe digital classroom catechesis as a site of theological resistance, pastoral creativity, and pedagogical innovation. Rather than capitulating to data-driven efficiency, the framework privileges story over information, encounter over optimization, contemplation over acceleration, and personhood over algorithmic classification. By integrating Harari's critique of data centrality, McCrindle's generational mapping, and Pope Francis's relational pedagogy, the framework articulates a coherent theological–pedagogical vision. This vision equips catechists to design learning spaces that engage digital culture critically without surrendering spiritual depth. It affirms imagination, ethical discernment, and relational presence as core dimensions of faith formation. In this way, digital catechesis becomes capable of nurturing Generation Beta's spiritual agency within AI-mediated worlds.

In this study, ambient catechesis is proposed as a lens for naming forms of faith formation that arise organically within liturgical, relational, and informal ecclesial spaces rather than through formal instruction. It designates pedagogical moments in which the kerygma is encountered through presence, dialogue, ritual proximity, and shared experience. Operating through attentiveness, affective resonance, and narrative openness, ambient catechesis enables learners to integrate doctrine with lived faith. This concept extends digital religion and experiential pedagogy by recognizing that formation unfolds in distributed and relational ways that parallel AI-shaped learning ecologies. In doing so, ambient catechesis provides a theological–pedagogical bridge between sacramental life and digital classroom design while resisting dogmatic scientism.

Within this framework, ambient catechesis finds its theological grounding in Mary as a pedagogical paradigm of faith formation. Mary's response to God is neither instructional nor propositional but receptive, dialogical, and deeply relational. Her pedagogy unfolds through attentiveness, silence, embodiment, and accompaniment—qualities that mirror the dynamics of ambient catechesis in liturgical and informal ecclesial spaces. As the “influencer of God,” Mary does not control meaning but facilitates encounter, allowing the Word to take flesh within concrete human experience. This Marian paradigm challenges catechetical models shaped by dogmatic scientism and offers a formative template for digital catechesis in AI-mediated environments, where learning increasingly occurs through presence, resonance, and relational mediation rather than linear instruction.

Method

Research Design

This study utilizes a qualitative, descriptive–analytical research design. The focus is on examining Catholic Religious Education (CRE) dynamics for Generation Beta within digitally mediated classrooms. The methodology prioritizes the interpretation of lived experience, relational interaction, and pedagogical meaning-making, rather than quantifying outcomes. This approach enables nuanced exploration of how catechesis is enacted and negotiated within AI-influenced environments. Attention is paid to how digital platforms shape learners' attention, participation, and symbolic understanding of faith. This qualitative orientation is essential for investigating faith formation, which relies on encounter and relational presence. Data collection will therefore focus on reflective observation and

narrative accounts to capture the complex, emergent nature of digital religious identity.

Research Sites and Participants

The research was conducted in kindergarten classrooms across diverse socio-cultural and ecclesial contexts in the Jakarta Special Region, Central Java, the Yogyakarta Special Region, and East Java. Participants included final-year Generation Alpha learners, who served as empirical proxies for the emergent Generation Beta (beginning 2025). Their involvement provided critical insights into early patterns of digital engagement, attention, and meaning-making relevant to Beta learners. Additionally, Catholic Religious Education teachers actively involved in classroom catechesis were interviewed and observed. Teachers were purposively selected based on their experience designing and facilitating digital or hybrid catechetical practices. This enabled rich reflection on pedagogical challenges, adaptations, and emerging possibilities within digitally mediated catechesis.

Data Collection

Data were collected through complementary strategies to ensure depth and triangulation. Semi-structured interviews with teachers and learners explored pedagogical assumptions, patterns of engagement, and the influence of digital tools and AI-mediated environments on catechesis. Classroom observations and site visits examined learning spaces, materials, and catechetical artifacts, including learners' creative outputs and instructional designs. In addition, digital documents such as lesson plans and learning modules were analyzed to trace how pedagogical intentions are enacted and mediated through digital platforms. Together, these methods enabled a holistic understanding of digital classroom catechesis as a relational, narrative, and technologically mediated practice.

Data Analysis

Data analysis followed thematic procedures adapted from Creswell (2014, 2015, 2022), Cresswell and Baez (2021), Cresswell and Poth (2018), Cresswell and Cresswell (2023), and interpretive strategies outlined by Silverman (2013, 2015, 2019, 2023). Interview transcripts, field notes, observational records, and digital artifacts were consolidated into a unified data corpus. Open coding was conducted to identify initial categories, including teachers' assumptions about learner readiness, modes of digital integration, relational strategies, and patterns of inquiry-based learning. Axial coding subsequently refined these categories by examining relationships among themes, guided by the study's theoretical lenses: Harari's anthropology of data, McCrindle's generational theory, and Pope Francis's relational pedagogy. This iterative analytical process enabled the emergence of conceptual themes that frame digital classroom catechesis as a space of encounter, narrative formation, and ethical engagement.

Trustworthiness and Ethical Considerations

Validity and trustworthiness were ensured through member checking and peer debriefing with scholars in digital pedagogy, qualitative research, and catechetical studies. Ethical protocols, including informed consent, confidentiality,

and encrypted data management, were rigorously observed, addressing both standard research ethics and concerns arising from AI-mediated learning. This methodological design aligns with the theoretical framework by capturing artificial intelligence as a formative environment, Beta learners' digital dispositions, and the shifting role of catechists as facilitators of grace. Consequently, it offers sufficient descriptive richness and analytical depth to examine how digitally mediated catechesis can foster relational, narrative, and ethically grounded faith formation.

Findings and Discussion

Research Findings

The research reveals a pronounced gap between teachers and students in classroom catechesis. Teachers often enter the classroom as “digital immigrants,” while students arrive as “digital natives.” The pre-digital orientation of teachers frequently manifests in classroom practices, where they feel constrained by limited instructional time and compelled to deliver as much doctrinal content as possible, believing students require it for faith formation. In contrast, students often experience this approach as receiving answers to questions they never asked. Classroom catechesis has yet to become a genuine “meeting point” between teachers and students, and students are rarely recognized as “digital citizens,” let alone as participants in an emerging AI-shaped world.

The integration of digital pathways in classroom catechesis remains a complex challenge. Younger teachers may find using digital applications to be a natural part of their professional routine, yet this often remains at the level of “user” engagement. While such efforts are commendable, effective digital catechesis requires teachers to incarnate themselves within digital culture—not merely to use tools, but to participate fully as “digital citizens.” This deeper immersion transforms the classroom experience, shifting pedagogy from procedural engagement to relational and culturally attuned interaction. Such participation enables catechists to discern learners' digital life worlds from within, fostering authenticity, trust, and meaningful theological encounter.

Informants report that artificial intelligence is primarily employed to streamline administrative tasks. Teachers recognize the time-intensive nature of managing assessments and student performance data, but have not yet applied AI to core content formation, such as Scripture, Tradition, and Magisterial teachings. The digital culture has not yet entered these essential domains, leaving the substantive content of Catholic education largely untouched by AI. Consequently, without teachers' active engagement in this area, the cognitive and spiritual demands on students remain heavy, and the potential of AI to enhance meaningful learning is underutilized. This gap signals the need for intentional pedagogical imagination that integrates AI critically and theologically into the heart of catechetical formation.

The challenges are compounded by teachers' reliance on standard textbooks, which often validate and reinforce the practice of “dogmatic scientism” in catechesis. Many textbooks merely replicate the Catechism and official Church documents verbatim, with minimal effort to contextualize or inculturate the kerygma for contemporary learners. Teachers present the materials verbatim, hoping students encounter the *kerygma*; without adaptation, the content risks becoming abstract, inaccessible, and disconnected from students' realities. For

many teachers, adapting the kerygma to digital culture is mistakenly perceived as compromising its integrity. As a result, Catholic education in the classroom often equates to rote memorization of doctrinal content, leaving Jesus figuratively as a “mummy” in the “museum” of Christianity, while digital culture and AI are viewed as threats rather than opportunities for enlivening the kerygma.

In response to these challenges, students demonstrate a remarkable capacity to resist dogmatic scientism through aesthetic engagement. In classroom settings, learners frequently employ drawing, dramatization, games, and the adaptation of popular song lyrics to express Catholic kerygma. Even when simple, these creative strategies reflect an intuitive critique of rigid content delivery and a desire to experience the kerygma as relevant and alive. Such practices reveal that learners seek meaning through embodiment, imagination, and shared experience rather than through abstraction alone. They also suggest that aesthetic expression functions as an entry point for deeper theological reflection when pedagogically recognized and intentionally cultivated. Attending to these impulses enables catechesis to align more closely with learners’ lived epistemologies and to foster faith formation that is both participatory and transformative.

When formal classroom catechesis fails to bring the kerygma to life, students often seek alternative spaces to engage meaningfully with the Gospel. Liturgical celebrations, particularly the Eucharist, frequently serve as vital sites for this “shadow catechesis.” These liturgical moments provide students with a rare opportunity to experience faith narratively, aesthetically, and digitally in ways that resonate with their generational sensibilities. They offer spaces where Alpha learners can manifest their creativity, reinterpret liturgical texts, and explore faith within a participatory, experiential framework. In these settings, students express a deep yearning for a living kerygma, and they engage the liturgy in ways that bring classroom teachings to life.

Consequently, Eucharistic celebrations and the informal encounters that follow often serve as spaces of ambient catechesis. Alpha learners use these moments to engage in reflective dialogue with priests, exploring themes and questions not addressed in formal classroom sessions. Though occurring outside structured lessons, these interactions are memorable and meaningful, providing relational spaces where students’ lived faith intersects with the kerygma. Such experiences highlight the importance of relational and experiential pedagogy, showing how liturgical and informal spaces can complement and extend traditional catechesis. Insights from these practices inform digital catechesis for the emerging Beta generation, emphasizing narrative, relational, and experiential approaches that center learners’ lived realities.

Finally, the findings highlight Mary as a pedagogical exemplar. Pope Francis’s description of Mary as the ‘influencer of God’ (*CV* 44) models catechists as relational guides and digital ‘facilitators of grace.’ By embodying her fidelity, courage, and openness, teachers engage digital catechesis not merely as content deliverers but as active “influencers of God,” fostering encounter, relational wonder, and transformative engagement among Beta learners. This approach emphasizes accompaniment, attentiveness, and narrative mediation in digitally mediated spaces while integrating aesthetic, relational, and ethical dimensions of faith formation. Ultimately, it bridges empirical observations with the Theoretical

Framework, showing how AI, generational theory, and relational pedagogy converge to shape the future of classroom catechesis.

Discussion

The findings from classroom observation, teacher interviews, and site analyses converge to illuminate a complex interplay between digital culture, generational disposition, and catechetical practice. Teachers' persistent adherence to dogmatic scientism, their perception of digital tools as threats, and the uncritical reliance on standardized textbooks reveal that classroom catechesis remains structurally tethered to pre-digital epistemologies. This tension mirrors Harari's critique of data centrality: as students' attention, identity, and learning experiences become increasingly mediated by algorithmic and AI-driven environments, traditional catechetical approaches struggle to remain relevant. Late-Alpha learners—the immediate precursors to Generation Beta—already demonstrate learning dispositions characterized by interactivity, visual richness, and immediate feedback, confirming McCrindle's observations that digital-native learners require pedagogies that are relational, narrative-driven, and technologically fluent.

Pope Francis's vision of relational pedagogy provides a critical interpretive lens for these findings. The study confirms that catechesis, when treated primarily as content transmission, fails to resonate with learners accustomed to immersive, multimodal environments. Teachers who maintain a pre-digital, dogmatic approach inadvertently reduce kerygma to information, symbol to definition, and encounter to knowledge transfer. This dynamic reflects the epistemological gravity of scientism, which the digital environment intensifies by rewarding efficiency, speed, and measurable outcomes. Yet, these same digitally mediated ecosystems offer unprecedented opportunities for pedagogical creativity. The digital landscape, when approached with discernment, becomes an arena for narrative engagement, aesthetic mediation, and relational encounter—echoing Pope Francis' insistence that catechesis must be an encounter with Christ, not a mere recitation of doctrines.

The integration of Mary as the “influencer of God,” as emphasized in *Christus Vivit*, deepens this interpretive framework by offering a concrete model for digital catechesis. Mary's relational authenticity, availability, and courage provide an embodied exemplar for teachers navigating AI-shaped learning spaces. In this paradigm, catechists are called to facilitate influence rather than assert authority, cultivating faith through accompaniment, narrative modeling, and intentional engagement with learners' lived realities. When deployed in digital classrooms, this vision positions teachers as “facilitators of grace,” guiding students toward perceiving God's activity amidst algorithmically mediated experiences, while maintaining theological integrity and relational depth.

The findings further indicate that liturgical and informal spaces, particularly Eucharistic celebrations, serve as crucial sites of ambient catechesis. Students leverage these encounters to bring the kerygma alive, translating doctrinal content into narrative, aesthetic, and digital forms that resonate with their generational sensibilities. These observations underscore the necessity of integrating *via narrativa*, *via pulchritudinis*, and *via digitalis* into classroom catechesis. Narrative pedagogy reopens imagination and situates learners' lives within the story of salvation; aesthetic engagement cultivates wonder and the capacity to apprehend transcendence; and intentional digital integration equips students to navigate AI

ethically while fostering relational presence and discernment. Together, these pathways constitute a theological and pedagogical countermeasure against scientism and reductive digital epistemologies.

By connecting these empirical insights to the theoretical framework, it becomes evident that digital catechesis for Generation Beta must represent a paradigmatic shift. Teachers can no longer function primarily as content managers; they must inhabit the digital ecology with theological literacy, ethical discernment, and relational attunement. Digital classrooms should not merely convey information but serve as laboratories of encounter, narrative exploration, and spiritual formation. AI, algorithms, and interactive platforms are to be embraced as tools to enhance imagination and relational connection, not as sources of doctrinal authority. In this sense, digital catechesis is both a pedagogical and theological project: it resists the reduction of mystery to data, restores relational and aesthetic dimensions to learning, and cultivates the capacities necessary for faith to flourish in an AI-mediated world.

Finally, the findings highlight Mary as a pedagogical exemplar. Pope Francis's description of Mary as the 'influencer of God' (CV 44) models catechists as relational guides and digital 'facilitators of grace.' By embodying her fidelity, courage, and openness, teachers engage digital catechesis not merely as content deliverers but as active influencers of God, fostering encounter and transformative engagement among Beta learners. This approach emphasizes accompaniment, attentiveness, and narrative mediation in digitally mediated spaces while integrating aesthetic, relational, and ethical dimensions of faith formation. Ultimately, it connects empirical observations with the Theoretical Framework, showing how AI, generational theory, and relational pedagogy converge to shape the future of classroom catechesis.

Conclusion

This study concludes that the main barrier to effective digital catechesis for Generation Beta is dogmatic scientism, which reduces faith to information and weakens relational encounter. In AI-saturated environments, this reductionism is intensified by algorithmic logics shaping knowledge and engagement. Drawing on the author's insights, transformative digital catechesis integrates narrative meaning, aesthetic mediation, and critically engaged digital pathways, supported by relational accompaniment and ethical discernment. Mary functions as a pedagogical paradigm—an "influencer of God"—modeling receptivity and fidelity amid technological acceleration. Resisting dogmatic scientism is thus a theological and pedagogical imperative, reclaiming catechesis as a sacramental, hope-filled encounter with Christ while equipping Generation Beta with spiritual depth and moral agency in an AI-shaped world.

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THE DEVELOPMENT OF COMPUTATIONAL THINKING MODULES FOR GRADE VII STUDENTS TO IMPROVE PROBLEM-SOLVING SKILLS

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Received: 17 January 2026; Accepted: 21 January 2026

Abstract

This study aims to develop a computational thinking module for seventh-grade students. The type of research is research and development. The method used is ADDIE. The research was conducted by analyzing students' needs for computational thinking modules. The needs analysis stage is carried out by collecting data regarding the curriculum used by the school, the curriculum regarding coding and artificial intelligence, and school development in the self-improvement class subject. Based on these needs, the modules were designed and developed according to learning outcomes and school characteristics. The implementation was conducted in SMP Islam Al Azhar 26 Yogyakarta on July 2025.

Keywords: computational thinking, module, problem-solving

Introduction

Schools with special characteristics, whether oriented toward strengthening religious values, national identity, cultural heritage, or specific academic programs, face unique challenges in designing learning experiences that align with the needs of the 21st century. Many of these institutions integrate the national curriculum with institutional or international curricula such as the Cambridge Curriculum to provide students with a comprehensive and globally relevant education. This combination requires instructional approaches that balance academic achievement, character development, and global competencies.

In schools with religious specializations, teaching and learning emphasize not only cognitive development but also moral values, ethical conduct, and the cultivation of disciplined behaviors that reflect specific spiritual traditions. Meanwhile, schools with national character specializations tend to focus on values such as integrity, cooperation, love of country, civic responsibility, and leadership. There are also schools that specialize in technology, science, arts, or adopt unique learning cultures and disciplinary frameworks. These diverse institutional identities indicate that each school requires pedagogical approaches designed to fit its specific characteristics and educational goals.

At the same time, students in schools with special characteristics must develop essential global competencies, including critical thinking, creativity,



innovation, communication, collaboration, and digital literacy. These competencies form the foundation of Higher Order Thinking Skills (HOTS), which are increasingly important in a rapidly changing digital society. Teachers, therefore, need to adopt instructional strategies that do not merely transmit information but challenge students to analyze, problem-solve, and make informed decisions independently.

Computational Thinking (CT) is one instructional approach that aligns well with these needs. CT emphasizes problem-solving through decomposition, abstraction, pattern recognition, and algorithm design. Beyond programming, CT serves as a cognitive framework that can be applied across subject areas to strengthen students' analytical and critical thinking skills. Research demonstrates that CT supports digital literacy, creativity, and logical reasoning—competencies that are vital for navigating global challenges.

Several specialized schools have begun introducing digital learning programs, science and technology classes, or global competency enhancement initiatives to address these evolving demands. However, the implementation of CT remains limited and often inconsistent due to the absence of systematic instructional designs that integrate CT with the school's distinct identity—whether religious, nationalistic, or academically focused.

Therefore, there is a need for a learning design that embeds Computational Thinking in a contextual manner that aligns with the profile and characteristics of schools with specializations. Such a design should provide practical guidance for teachers to implement CT through project-based learning, real-world problem-solving, and meaningful digital activities while preserving each school's unique identity. Effective CT integration has the potential not only to strengthen academic achievement but also to support character development and global competence among students.

Literature Review

Computational thinking (CT) has become a foundational competence in modern education, particularly as schools strive to prepare students for an increasingly digital and interconnected world. Wing (2006) introduced CT as a universal skill that involves problem decomposition, abstraction, algorithmic design, and evaluation. Those skills are essential not only for computer science but also for broader problem-solving across disciplines. Since then, extensive research has highlighted the importance of integrating CT into middle-school curricula to cultivate higher-order thinking, creativity, and analytical reasoning in students (Grover & Pea, 2013). CT is also viewed as a bridge connecting technology-enhanced learning with conventional subject domains such as mathematics and science, generating meaningful learning experiences that reflect real-world reasoning processes (Czerkowski & Lyman, 2015).

Studies further emphasize that effective CT integration requires structured learning environments, authentic tasks, and clear scaffolding. For example, Weintrop et al. (2016) demonstrated that CT can be embedded within STEM activities through modeling, simulation, data practices, and computational problem-solving. These strategies help students understand abstract concepts through hands-on digital exploration. Similarly, Shute et al. (2017) found that CT skills can be developed through game-based environments that encourage students to engage in

experimentation, iteration, and reflection. Their findings underscore that CT is not merely about mastering tools but about cultivating cognitive habits that support systematic thinking.

In the context of schools with particular characteristics, such as those emphasizing religious values or national character formation, CT can strengthen holistic student development. Research shows that CT does not conflict with religious or character-based education; instead, it enhances students' ability to make thoughtful decisions, reason clearly, and collaborate effectively (Mohaghegh & McCauley, 2016). Schools with specialized missions, whether oriented toward religious identity or national character building, often aim to develop moral reasoning, disciplined thinking, and social responsibility. CT supports these goals by providing structured problem-solving frameworks that align with value-based education. For instance, integrating CT into project-based learning environments helps reinforce perseverance, collaboration, and ethical decision-making, competencies aligned with character-oriented educational missions (Lye & Koh, 2014).

Recent studies highlight the need for localized CT implementation models that match school context, student readiness, and institutional vision, demonstrating CT integration aligned with school culture and supported by professional development for teachers. This aligns with the objectives of schools that blend conventional curricula with specialized programs, such as digital literacy, STEM enrichment, or value-based learning. Additionally, computationally enriched science classrooms, like those described by Lee et al. (2020), highlight how CT can enhance inquiry-based learning, promote interdisciplinary understanding, and foster global competencies become key components for schools aiming to prepare students for international academic standards.

Overall, the literature consistently shows that CT integration benefits students not only cognitively but also socially and ethically. When implemented within structured programs, such as digital science classes or specialized improvement tracks, CT can provide pathways for students to strengthen global skills, character values, and readiness for future academic challenges. The body of research also affirms the importance of designing CT lessons that resonate with local school identities and aspirations, ensuring that computational thinking becomes a powerful tool for holistic and culturally aligned education.

Method

This study adopted an ADDIE-based research and development model comprising analysis, design, development, implementation, and evaluation stages. The analysis stage examined instructional needs, learner characteristics, and curriculum requirements related to Computational Thinking. The design stage focused on developing learning objectives, instructional scenarios, and evaluation instruments. In the development stage, CT-based learning materials were developed and revised based on expert validation. The implementation stage involved a limited trial in a real classroom setting. Finally, the evaluation stage assessed the practicality and implementation of the learning materials.

Data were collected using expert validation instruments, practicality questionnaires administered to teachers and students, and observation sheets of learning implementation. The collected data were analyzed descriptively to

determine the validity, practicality, and feasibility of the developed CT-based learning materials.

Findings and Discussion

ADDIE Analyze Stage

The analysis stage of the ADDIE model was conducted to identify the initial conditions of learning, the competency gaps, and the specific needs of students and teachers in implementing Computational Thinking (CT) within a school with particular characteristics. Although the school integrates national, foundation-based, and international curricula and aspires to develop students who are character-driven, high-achieving, and globally competent, classroom practices do not yet fully reflect these expectations. The demand for higher-order thinking skills, digital literacy, and technology-integrated problem solving has not been optimally aligned with the learning experiences currently provided, highlighting the need for a more systematic approach to embedding CT in instruction while maintaining the school's unique values and identity.

From the learner perspective, classroom observations and the researcher's teaching experience indicate that students possess basic digital literacy and show enthusiasm for technology-supported learning. However, many students are not yet accustomed to applying CT strategies such as decomposition, abstraction, pattern recognition, and algorithmic thinking in solving problems. Learning activities tend to be procedural and outcome-oriented, offering limited opportunities for students to engage in systematic, reflective, and exploratory thinking. This condition demonstrates a clear need for instructional guidance that supports students' development of structured thinking through project-based activities, simulations, and exploratory tasks.

Curricular analysis and interviews with teachers also reveal that existing lesson plans do not explicitly incorporate CT elements. Teachers require structured models and actionable instructional steps to integrate CT consistently and meaningfully into classroom instruction. Although the school provides adequate technological infrastructure and operates a technology-oriented special program, these resources have not yet been fully utilized to promote CT-based learning. Teachers need pedagogical support that bridges technological tools with CT-oriented learning processes.

Based on these findings, the primary needs include: (1) instructional materials that explicitly guide the integration of CT, (2) learning activities that promote systematic and project-based thinking, (3) enhanced teacher capacity to apply CT-oriented pedagogical strategies, and (4) more meaningful use of technology to support students' computational reasoning. This needs analysis establishes a strong foundation for the subsequent Design stage, ensuring that the instructional model to be developed directly addresses the identified gaps and aligns with both the school's character profile and curriculum expectations.

ADDIE Design Stage*Developing general CT learning scenarios*

Table 1. Learning Scenario

The Schedule	Learning Material	Subject collaboration
July- September 2025 (about 3 months)	CT plugged and CT unplugged	Informatics

- How students learn: Students will be introduced to CT shortly. Then, students will have some activities.
- Learning hours: 35 minutes each (70 minutes in a week)
- Introduction: learning objectives, learning methods; core learning: activities and ice breaking; closing: reflection

Planning worksheets containing four foundations/ core of CT

- Students will access the learning material using an electronic tablet
- The learning support by Google Classroom
- Some activities may still need paper as a worksheet
- Need teamwork

Simple classroom exercises

- Activity for session 1: how to introduce to every foundation of CT by examples
- Activity for session 2: learning phenomenon of CT's foundations
- And activities in each session should be finished by each student or team

ADDIE Development Stage

Table 2. General Development of the Media

General CT	Problem Decomposition	Pattern Recognition	Abstraction	Thinking Algorithm
The design	Students identify key components of a real-world problem and divide it into simpler sub-problems using guided questions and worksheets	Students compare multiple problem scenarios to recognize similarities, trends, or repeated structures that support solution development	Students select essential variables and information from contextual problems and represent them using diagrams, tables, or simplified models	Students design solution steps in the form of flowcharts, pseudo-code, or structured procedures to solve the given problems

The examples How people eat watermelon: usually people should slice the water melon become smaller parts to make it easier for the mouth People's daily activities become routine Many ways order of wearing shoes people get up in the morning

Appearance (example of the slides)

Dekomposisi Masalah: Problem Decomposition



Pengenalan Pola: Pattern Recognition



Abstraction atau Abstraksi



Algoritma Berfikir atau Algorithm



- Bagaimana urutan memakai Sepatu?
- kita duduk
- Ambil kaos kaki
- Pakai kaos kaki
- Ambil Sepatu
- Pakai sepatu

Apakah urutan bisa diubah?

activities

Komponen CT I: Dekomposisi Masalah

- Aku tinggal di Yogyakarta. Saat liburan, aku ingin pergi ke rumah nenek di Semarang. Untuk ke Semarang bisa lewat Magelang tapi bisa juga lewat Klaten.
- Supaya lebih cepat, aku perlu menyampaikan ke ayah supaya lewat mana?



Mari Melihat Pengenalan Pola

Nomor	Permasalahan	Jawaban
1	1,2,3,4,...	...
2	Satu, Dua, Tiga, Empat,...	...
3	▲ ▲ ▲ ▲ ▲ ▲ ▲ ▲	...
4	● ● ● ● ● ● ● ●	...
5	● ● ● ● ● ● ● ●	...

Selanjutnya...

- Kita akan belajar abstraksi



Mengendarai Sepeda

memanfaatkan abstraksi — menganggap sepeda sebagai alat yang bisa dikendalikan dengan kontrol sederhana tanpa harus memahami semua mekanismenya.

- Untuk bisa naik sepeda, kita tidak perlu tahu detail mengenai:
 - Warna sepeda, harga sepeda
 - Bagaimana memasang ban
 - Berapa berat sepeda
 - Siapa yang membuat sepeda?
 - Bagaimana memasang gigi atau gear



Apa yang akan kita pelajari hari ini?

- Memahami Input, Proses, Output
- Memahami cara memasukkan data ke dalam program Stracth
- Memahami cara menampilkan tampilan dalam program Scratch
- Membuat gim sederhana dengan Scratch

Examples of
assessment

6 pertanyaan • 16 Poin Tunjukkan jawaban ☒

1. PILIHAN GANDA • 30 detik • 2 poin Review Edit

Ketika kita memiliki masalah yang besar dan rumit, langkah pertama yang dapat kita lakukan agar masalahnya menjadi lebih mudah diselesaikan adalah

☒ Dekomposisi masalah ☐ Pengenalan pola
☐ Abstraksi ☐ Algoritma

2. PILIHAN GANDA • 30 detik • 2 poin

Ketika menyusun langkah-langkah untuk menyelesaikan masalah yang kita hadapi, sebenarnya kita sedang melakukan

☐ Dekomposisi masalah ☐ Pengenalan pola
☐ Abstraksi ☒ Algoritma

Aktivitas 7-2: Membuat program penjumlahan

5.	Susun blok untuk meminta pengguna memasukkan angka pertama.	
6.	Tambahkan blok untuk menyimpan angka pertama ke variabel angka1.	
7.	Tambahkan blok untuk: - meminta pengguna memasukkan angka kedua - menyimpan angka kedua ke variabel angka2.	

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ADDIE Implementation Stage

Implementation Schedule

Table 3. Implementation Schedule

No	Date	Activities	Note
1	July 28, 2025	General CT and Problem Decomposition	Students' activities, homework, and CT unplugged
2	August 4, 2025	Pattern recognition	Students' activities and CT unplugged
3	August 11, 2025	Abstraction	Students' activities and CT unplugged
4	August 25, 2025	Thinking algorithm part 1: algorithm and flowchart	Small project (scratch) and CT plugged
5	September 8, 2025	Thinking algorithm part 2: Scratch programming	CT plugged
6	September 15, 2025	Thinking algorithm part 3: implementation of CT for game development	CT plugged

Students' Responses while Learning Foundation of CT's

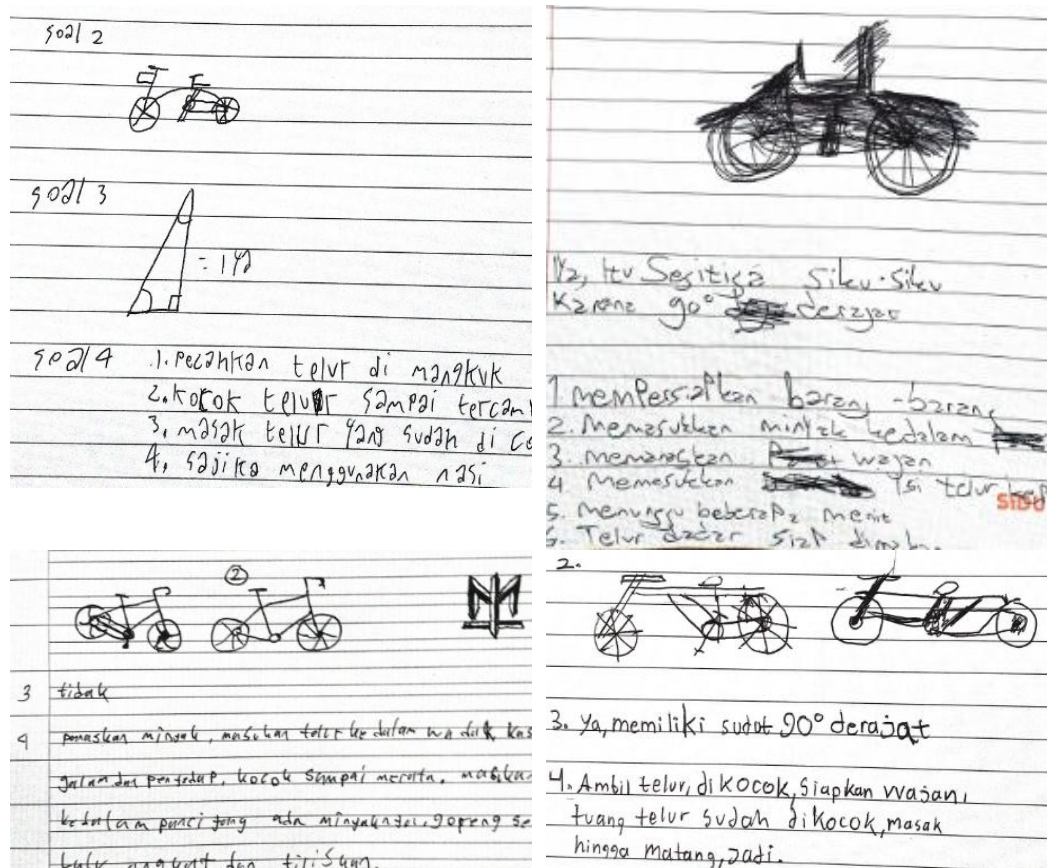


Figure 1. Examples of Students Responses

ADDIE Evaluation Stage

Table 4. The Analysis Stage

No	Practical Analysis	Comments or notes
1	Easy to use for teachers and students	Very practical
2	Feasible to implement in real classroom settings	practical
3	Efficient in terms of time and resources	Practical
4	Support the learning process without significant technical obstacles	Very practical

Conclusion

This study aimed to develop Computational Thinking learning media using the ADDIE instructional design model. The development process systematically followed the five stages of ADDIE, namely Analysis, Design, Development, Implementation, and Evaluation.

The results of the study indicate that the developed Computational Thinking learning media are valid, practical, and effective. Expert validation confirmed that the media met content accuracy, instructional design quality, and usability criteria. Practicality evaluation showed that the media were easy to use and feasible for classroom implementation. Furthermore, summative evaluation demonstrated that

the media effectively supported students' understanding of Computational Thinking concepts, problem-solving skills, collaboration, and communication through project-based learning activities.

These findings suggest that the ADDIE model is an appropriate and systematic framework for developing Computational Thinking learning media that address real classroom needs. The developed media provide meaningful learning experiences and support the development of 21st-century skills. Therefore, the Computational Thinking learning media developed in this study can be used as an alternative instructional resource and further adapted to different learning contexts.

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