Proceedings of International Conference on Research in Education (ICRE) 2025, pp. 464-477
ISSN: 3124-4467
27-28 November 2025 - Yogyakarta, Indonesia
https://e-conf.usd.ac.id/index.php/icre
Fakultas Keguruan dan Ilmu Pendidikan, Universitas Sanata Dharma, Yogyakarta

DEVELOPING INTERACTIVE SNAKES AND LADDERS MEDIA TO ENHANCE STUDENTS' UNDERSTANDING OF REPRODUCTIVE SYSTEM CONCEPTS

Josua Nico Manurung[1*], I Made Enos Arya Teja[2], Yosefa Maria Dilva[3], Patricia Lusia Koeswulandari Shan Chai Irwanto[4], Luisa Diana Handoyo[5]
[1]Economic Education, Sanata Dharma University, Indonesia
[2-5]Biology Education, Sanata Dharma University, Indonesia
josuanicomanurung96@gmail.com[1], enosteja5@gmail.com[2], yosefamariadilfa@gmail.com[3]; solossapatricia112@gmail.com[4], luisadianahandoyo@usd.ac.id[5]
*Correspondence: josuanicomanurung96@gmail.com
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 Srikandhi 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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