UNIVERSITAS SEBELAS MARET
BIOEDUKASI: JURNAL PENDIDIKAN BIOLOGI
https://jurnal.uns.ac.id/bioedukasi
1693-265X (Print) | 2549-0605 (Online)

The Development of the Problem-Oriented Android Application SIREMA for Learning the Human Excretory System

Fina Nurul Arifah [a, 1, *], Eka Cahya Prima [a, 2], Djohar Maknun [b, 3], Mujib Ubaidillah [b, 4]

[a] Department of Science Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No.229, Bandung City, West Java, Indonesia
[b] Department of Biology Education, Faculty of Teacher Training and Education, UIN Siber Syekh Nurjati Cirebon, Jl. Perjuangan By Pass Sunyaragi, Cirebon City, West Java, Indonesia
[1] finaarifah13@upi.edu; [2] ekacahyaprima@upi.edu; [3] maknundjohar@gmail.com;
[4] mujib_ubaidillah@syekhnurjati.ac.id
* Corresponding author: finaarifah13@upi.edu

Submission : 04/12/2025
Revision : 04/08/2026
Accepted : 15/08/2026

ABSTRACT

The abstract nature of the human excretory system often presents significant challenges for high school students, resulting in suboptimal learning outcomes. This study aims to develop "SIREMA," an acronym for Human Excretory System, a problem-oriented Android application, and evaluate its feasibility, practicality, and effectiveness in enhancing cognitive skills. Using a Research and Development (R&D) approach with the ADDIE model, the study was conducted at SMA Negeri 3 Cirebon with 36 Grade XI students, along with subject and media experts. Data collection included interviews, expert validation sheets, teacher-practitioner validation questionnaires, and pretest-posttest instruments. The results demonstrated that SIREMA is "Very Feasible," achieving 99.1% in material validation and 84.4% in media validation. The application also demonstrated strong content validity based on teacher practitioners' judgment, reflected in a Content Validity Index (CVI) of 1.00, and achieved a 99% positive student response, indicating high practicality for classroom use. Furthermore, the application significantly improved learning outcomes, evidenced by a high N-Gain score of 0.88 and significant Wilcoxon test results ($p < 0.05$). In conclusion, SIREMA is a robust, interactive learning medium that facilitates independent learning and improves academic performance. This study contributes to biology education by offering an empirically validated, problem-oriented mobile learning medium that addresses persistent student misconceptions about the human excretory system and supports independent, technology-based learning in secondary science classrooms. Future research should test SIREMA with larger, more diverse samples, over longer implementation periods, and using experimental designs with control groups to strengthen further evidence of its impact on students' cognitive learning outcomes.

Keywords: ADDIE Model, Android Application, Cognitive Learning Outcomes, Human Excretory System, Problem-Based Learning

Introduction

Several digital learning media have been developed to address the challenges of teaching the human excretory system in Indonesian classrooms. Muninda et al. (2021) developed an Android-based flash learning medium focused specifically on the liver as an excretory organ for junior high school students; it was reported as highly feasible and practical but limited to a single organ and not structured around a specific pedagogical model. Prasetyo et al. (2022) designed an Adobe Animate-based Android application on kidney function for senior high school students to improve critical thinking skills, while Agustini et al. (2021) developed an Instagram-assisted digital comic to introduce excretory system concepts through static visual narratives. More recently, Haka et al. (2025) developed an interactive e-module combining augmented-reality holograms and text-to-speech features for excretory system material at the junior high school level. Although these products have improved feasibility and student engagement, they generally address only a single excretory organ, rely on linear or non-interactive content delivery, and are not explicitly structured around a problem-solving pedagogical syntax that guides students through authentic, case-based investigation. This gap points to the need for a comprehensive, problem-oriented Android application that integrates the full scope of excretory system content within an interactive, Problem-Based Learning (PBL)-structured environment. This study addresses this gap by developing SIREMA, which distinguishes itself from prior digital products by embedding the five stages of PBL directly into its navigation structure alongside interactive 3D organ models.

In this context, Problem-Based Learning (PBL) has emerged as an evidence-based approach that effectively strengthens biology and science education. Studies have shown that PBL can enhance student engagement, critical thinking skills, and conceptual mastery across various settings (Anggraeni et al., 2023; Kasuga et al., 2022; Usman et al., 2024). Empirical evidence also demonstrates that integrating PBL with literacy or STEM activities leads to significant improvements in learning outcomes (Auliyani et al., 2025; Kasuga et al., 2022; Sakti, 2025). This approach is particularly relevant for complex topics such as the human excretory system, where students often hold misconceptions about kidney function, the mechanisms of urine formation, and inter-organ integration (Bonita et al., 2024; Din-Yan, 1998; Ristanto et al., 2021). Interview data further indicate that many students feel cognitively overwhelmed and lack confidence despite repeatedly studying the material (Cezar & Maçada, 2023). Overall, these findings reinforce the importance of adopting student-centered strategies such as PBL to address conceptual barriers while improving the quality of biology education at both national and global levels.

The integration of digital technologies, including interactive simulations, virtual laboratories, and adaptive platforms, has been shown to enhance engagement and conceptual understanding in biology learning (Nurdin et al., 2025; Yususf et al., 2025). Problem-Based Learning (PBL) has been found to improve critical thinking skills and learning outcomes among biology students (Usman et al., 2024; Wahdaniyah et al., 2023), while mobile applications have proven effective as supplementary learning tools that increase motivation and academic performance (Anggraeni et al., 2023; Mutiara et al., 2024). Nevertheless, research gaps remain concerning Android-based applications specifically designed for excretory system content, as well as the development of problem-solving skills within biology instruction.

Students' understanding of the excretory system remains low due to the complexity of physiological mechanisms and the abstract nature of biological terminology (Rizalia et al., 2024). Biology learning applications are often criticized for limited interactivity and

insufficient focus on problem-solving, which reduces their effectiveness, particularly without student–teacher interaction or peer collaboration (Afrianti & Maryatun, 2025; Nurdin et al., 2025). Additionally, incorporating multimedia components like interactive tests and animations is thought to be crucial for improving conceptual understanding and motivation (Ngandoh et al., 2025). Developing interactive-based applications is therefore crucial for improving students' conceptual comprehension and problem-solving skills. Digital learning environments have been shown to increase participation, motivation, and academic achievement (Sihotang et al., 2025). In addition, integrating practical and interactive components directly supports science process skills, which positively correlate with biology learning outcomes (Ilma et al., 2020).

Because biology is an abstract subject with a lot of technical jargon, biology content, including the excretory system, is frequently thought to be hard for students to understand (Rizalia et al., 2024). Additionally, many students have misconceptions, especially about human organ systems like the excretory system (Andariana et al., 2020). Students' critical thinking abilities in biology courses have been demonstrated to be improved by the Problem-Based Learning (PBL) approach (Usman et al., 2024). However, students may experience cognitive overload if PBL is not supported by suitable learning resources (Ghani et al., 2021). Therefore, implementing PBL requires support through interactive media to ensure more effective learning processes (Nurhasanah et al., 2024).

Additionally, mobile learning has been shown to boost students' motivation and engagement in science classes (Sangur et al., 2025). Specifically, Android-based applications in biology instruction have been shown to improve students' learning outcomes (Raistanto et al., 2024). Multimedia learning principles also emphasize that integrating text, images, and animations can help reduce students' cognitive load (Mayer, 2009). Accordingly, well-designed multimedia-based instruction, such as the SIREMA application, can optimize cognitive load while enhancing students' understanding of complex biological concepts.

The SIREMA application, an acronym for Sistem Ekskresi Manusia (Human Excretory System), was developed as an Android-based digital learning medium for Grade XI high school biology students. This innovation was created in response to challenges frequently encountered in biology learning, particularly the human excretory system, which is often perceived as abstract and difficult to understand because of its complex physiological mechanisms and technical terminology. SIREMA is designed to be interactive and problem-oriented. Accordingly, this study aims to develop and evaluate the problem-based SIREMA Android application as a digital learning medium for the human excretory system.

Specifically, the study addresses the following research questions: (1) How is the development process of the problem-based SIREMA Android application for learning the human excretory system? (2) How feasible is the SIREMA application as a digital biology learning medium? (3) How practical is the use of the SIREMA application in supporting students' understanding of the human excretory system? This study aims to develop and evaluate the problem-oriented Android application SIREMA for the human excretory system to support students' learning autonomy, improve conceptual understanding, and enhance cognitive skills. This study's findings are expected to provide both theoretical and practical contributions to integrating mobile learning and problem-based pedagogy in biology education. The following section outlines the methods employed to achieve these objectives.

Methods

Research Design and Model

This study employed a Research and Development (R&D) approach to produce an Android-based application called SIREMA. The study adopted the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) development model, which provides a

systematic framework and allows for continuous evaluation at each stage. To evaluate the practicality and practitioner-judged content validity of the application, a small trial involving 36 students and five biology teachers was conducted during the Implementation stage of this study. Meanwhile, the Evaluation stage included formative evaluation through expert validation and summative evaluation using students' cognitive learning outcomes.

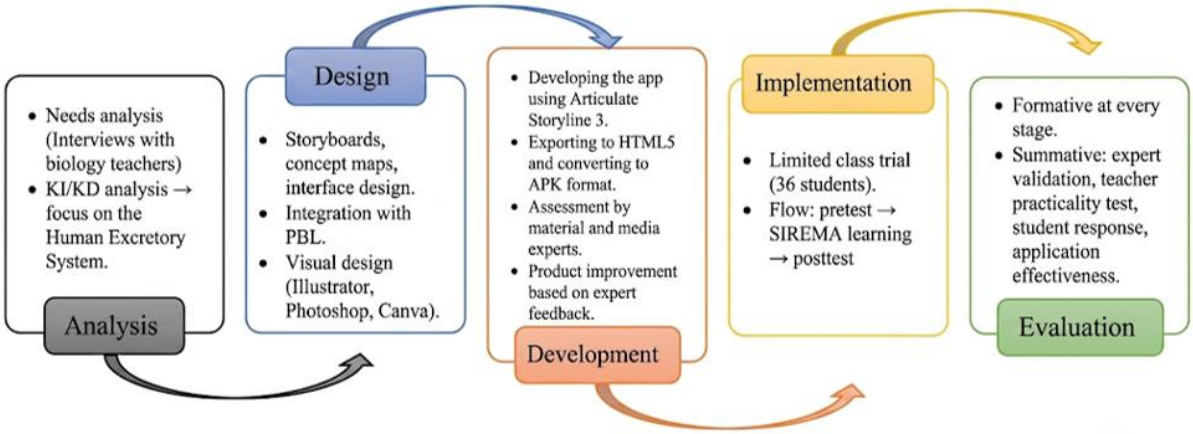

Figure 1. Research design and model of the SIREMA application using the ADDIE model

Product Trial Design

To evaluate the product's effectiveness, this study used a pre-experimental design with a one-group pretest–Posttest Design. The design followed this pattern: students were administered a pretest, participated in learning activities using the application, and then completed a posttest to determine whether learning outcomes changed.

Table 1. One-group pretest–posttest research design

Pretest	Treatment	Posttest
O_1	X	O_2

Description:
O_1: Pretest administered before the treatment
O_2: Posttest administered after the treatment
X: Treatment given to the experimental group, namely the use of the problem-oriented Android application "SIREMA"

Research Participants

The participants in this study were 36 students from Grade XI MIPA 5 at SMA Negeri 3 Cirebon, purposively selected as subjects for a limited trial of the SIREMA application. In addition, expert and practitioner involvement was an important component of this research. Five lecturers from UIN Siber Syekh Nurjati Cirebon conducted product validation, comprising two media experts and three subject-matter experts, to ensure content accuracy and design quality. Meanwhile, the practitioner validation test involved five biology teachers from various schools (SMA Negeri 3 Cirebon, MA Khas Kempek, SMAIQu Al-Bahjah, and MAN 2 Bekasi) to assess the application's relevance and suitability within real classroom contexts.

Data Collection Techniques and Instruments

Data were collected using three primary techniques: interviews, questionnaires, and learning outcome tests. At the initial stage, interviews were conducted to identify instructional needs

and challenges encountered in biology learning. Subsequently, questionnaires were employed to measure content validity, practitioner judgment, and user responses. These included validation questionnaires for subject-matter and media experts (Likert scale), validation questionnaires for teacher practitioners (Likert scale, analyzed using CVR/CVI), and response questionnaires for students (Guttman scale). To assess improvements in cognitive ability, a learning outcome test consisting of 20 multiple-choice items was administered before (pretest) and after (posttest) the intervention.

Data Analysis Techniques

The collected data were analyzed using both quantitative and qualitative approaches. The qualitative data, obtained from the initial needs-assessment interviews and from experts' and practitioners' open-ended comments on the validation and practicality instruments, were analyzed descriptively using an interactive analysis procedure comprising data reduction, data display, and conclusion drawing. Interview transcripts were first condensed and coded to identify recurring themes related to students' learning difficulties and instructional needs concerning the excretory system; these themes were then organized into descriptive categories and used to inform the design and content of the SIREMA application. Written suggestions from validators and practitioners were analyzed in the same manner and used as the basis for product revision before trial implementation.

First, the results from the expert validation and student response questionnaires were analyzed descriptively by calculating the percentage of feasibility using the following formula:

$$P = \frac{\sum \quad x}{\sum \quad xi} \times 100\%$$

Where P is the percentage of feasibility, $\sum \quad x$ is the total score obtained, and $\sum \quad xi$ is the maximum ideal score. The results were then categorized into feasibility criteria: Very Feasible (81%-100%), Feasible (61%-80%), Less Feasible (41%-60%), and Not Feasible (≤40%). Meanwhile, the validation data obtained from teacher practitioners were analyzed using the Content Validity Ratio (CVR) to determine the essentiality of each item, followed by the Content Validity Index (CVI) developed by Lawshe to evaluate the overall instrument's content validity. An instrument is considered highly relevant and valid if the CVI value approaches 1.00.

Second, the effectiveness of the SIREMA application was measured by comparing pretest and posttest scores. The improvement in students' cognitive learning outcomes was quantified using the Normalized Gain (N-Gain) equation:

$$g = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}}$$

Where g is the N-Gain score, S_{post} is the posttest score, S_{pre} is the pretest score, and S_{max} is the maximum ideal score. The resulting N-Gain values were interpreted based on three categories: High ($g \geq 0.7$), Medium ($0.3 \leq g < 0.7$), and Low ($g < 0.3$).

Finally, to determine the statistical significance of improvements in learning outcomes, hypothesis testing was conducted using SPSS software. Prerequisite tests, including the Kolmogorov-Smirnov test for normality and the homogeneity test, were initially performed. Because the normality test indicated that the posttest data were not normally distributed, the non-parametric Wilcoxon Signed-Rank Test was employed. The significance level was set at $\alpha = 0.05$. If the Asymp. Sig. (2-tailed) value is < 0.05, the null hypothesis is rejected, indicating a

statistically significant difference in students' cognitive learning outcomes before and after using the SIREMA application.

Results and Discussion

Development of SIREMA Application

The SIREMA application was developed through systematic stages based on the ADDIE model: Analysis, Design, and Development. In the Analysis stage, problem identification revealed the need for a learning medium that could visualize the abstract mechanisms of the excretory system and support student autonomy. Based on these needs, the Design stage focused on creating engaging visual assets and intuitive navigation. The researchers employed a combination of software tools: Adobe Photoshop 2023 for creating 3D text effects and image manipulation, Adobe Illustrator 2020 for vector layout and character design, and Canva for assembling navigational icon elements. All visual assets were exported in transparent .PNG format to ensure high display quality during integration.

In the Development stage, product realization was conducted using Articulate Storyline 3. This software was selected for its ability to create interactive features without requiring complex programming, such as name input variables, triggers, and quizzes. The application consists of six main scenes: orientation/login, about the application, introduction, learning menu (core), content, and evaluation. Research on Articulate Storyline 3 for biology learning Amir & Lubis (2025) and Riyanto et al. (2024) has mainly involved developing interactive multimedia modules to enhance student engagement, understanding, and skills such as problem-solving and critical thinking in topics such as human physiology and ecology.

A personalization feature was included as the application's opening component to enhance student engagement. On the login page, a Text Entry Field feature allows students to input their name and class. These variables are then connected to specific triggers that enable the application to "greet" users by name on subsequent pages, creating a more personalized learning experience. The main interface (Main Menu) uses clearly defined navigation icons to make it easy to access features such as Basic Competencies, Concept Maps, and Core Material.

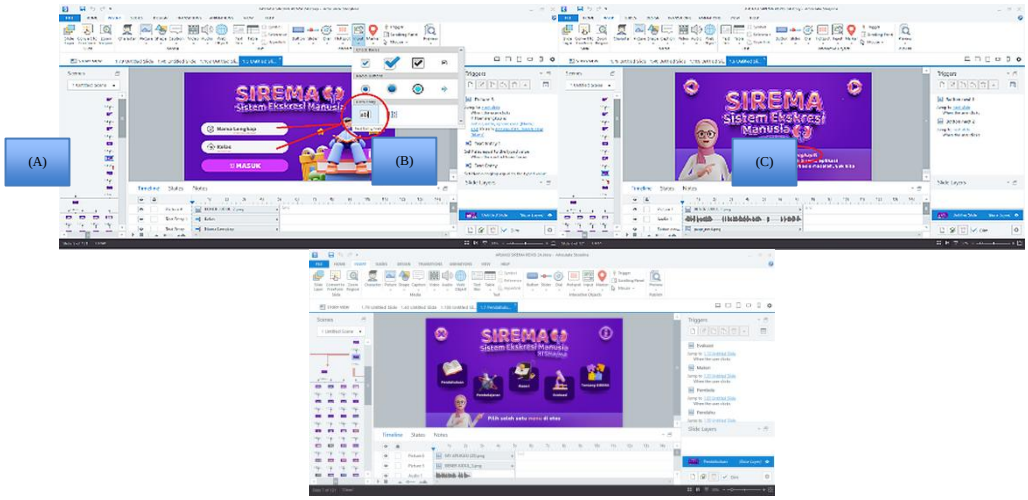

Figure 2. User Interface of SIREMA: (A) Login page with text entry; (B) Personalized greeting screen; (C) Main menu dashboard.

English translation of on-screen text: (A) "Nama" = Name, "Kelas" = Class, button "MASUK" = Log In. (B) "SIREMA - Sistem Ekskresi Manusia" = "SIREMA - Human Excretory System" (Grade XI SMA/MA), with a welcome greeting for the student. (C) "Pilih salah satu menu di atas" = "Select one of the menus above"; menu items "Pendahuluan" = Introduction, "Pembelajaran" = Learning, "Materi" = Material, "Evaluasi" = Evaluation, "Tentang SIREMA" = About SIREMA.

The SIREMA application moved on to the ADDIE model's Implementation and Evaluation stages after the Analysis, Design, and Development phases were finished. Formative evaluation, through expert and practitioner validation, had already been carried out during the Development stage to establish the product's content validity before classroom use. To assess the application's viability from the viewpoints of both teachers and students, a small-scale field trial was then conducted in the classroom during the Implementation stage, followed by summative evaluation to determine how well the application improved students' cognitive learning outcomes. The following sections present specific conclusions about feasibility, validity, practicality, and cognitive effectiveness from the implementation and evaluation phases.

Integration of Problem-Based Learning (PBL) Syntax

A distinct feature of SIREMA is the embedding of PBL syntax directly into the learning navigation. Unlike conventional media that presents material linearly, the "Learning" menu in SIREMA guides students through the five stages of PBL interactively: (1) Orientation to the Problem: Students are presented with authentic case studies (e.g., kidney disorders) displayed in a scrolling panel to facilitate comprehensive reading; (2) Organizing Students: An input field is provided for students to formulate initial hypotheses or questions regarding the case; (3) Individual/Group Investigation: Students explore the content using Interactive Object Markers on 3D organ models. Clicking these markers reveals detailed information, and specific buttons link to external videos for deeper understanding of bioprocesses. (4) Developing Artifacts: A structured column allows students to type and submit their solutions. (5) Analyzing and Evaluating: The application provides immediate feedback and scientific explanations to validate the students' problem-solving process. Careful and effective implementation of Problem-Based Learning (PBL) has consistently been shown to enhance essential student competencies, including critical and creative thinking skills, the ability to solve complex problems, and readiness for lifelong learning (Al-Aufi & Al-Balushi, 2023; Aldabbus, 2020). Figure 3 illustrates the implementation of these PBL stages within the application interface.

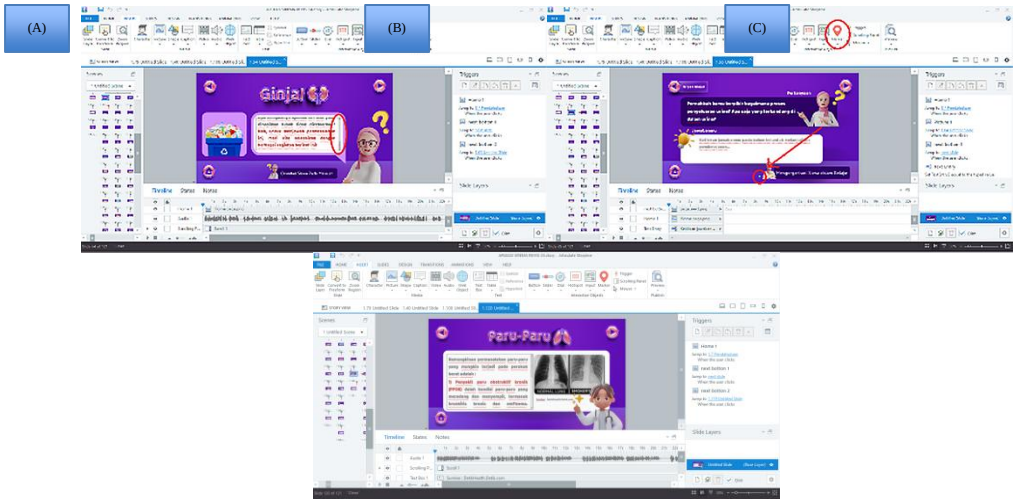

Figure 3. Implementation of PBL Syntax in SIREMA: (A) Problem orientation with scrolling panel; (B) Investigation stage using interactive markers on 3D kidney model; (C) Analysis and verification stage.

English translation of on-screen text: (A) "Ginjal" = "Kidney", presenting a real-world problem scenario related to kidney symptoms for students to analyze. (B) A guiding question on the mechanism of urine formation, with an interactive marker prompting students to investigate. (C) "Paru-Paru" = "Lungs"; text reads: "Possible lung problems that may occur in heavy smokers include: 1) Chronic Obstructive Pulmonary Disease (COPD), an inflamed and narrowed lung condition, including chronic bronchitis and emphysema." (Source: DetikHealth.com).

To measure cognitive mastery, the application includes an Evaluation menu containing 20 randomized multiple-choice questions. This feature utilizes the Graded Question system, which automatically calculates and displays the student's score upon completion. It also includes a Review Quiz feature that allows students to reflect on their answers and learn from mistakes (Figure 4).

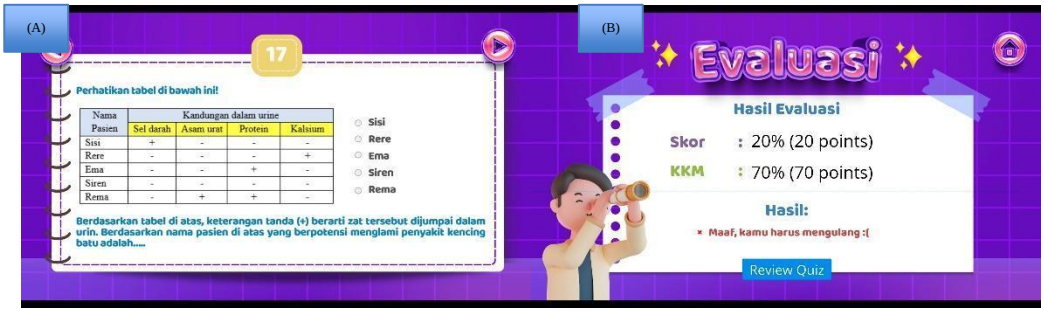

Figure 4. Features: (A) Interactive multiple-choice quiz interface; (B) Final score display with review options

English translation of on-screen text: (A) "Perhatikan tabel di bawah ini!" = "Look at the table below!"; table columns "Nama Pasien" = Patient Name, "Kandungan dalam urine" = Content in urine ("Sel darah" = Blood cells, "Asam urat" = Uric acid, "Protein", "Kalsium" = Calcium); question: "Based on the table above, a (+) sign indicates the substance was found in the urine. Based on the patient names above, the one potentially suffering from kidney-stone disease is....." (B) "Evaluasi" = "Evaluation"; "Hasil Evaluasi" = "Evaluation Result"; "Skor" = Score: 20% (20 points); "KKM" = Minimum Mastery Criterion: 70% (70 points); "Hasil" = Result: "Maaf, kamu harus mengulang :(" = "Sorry, you need to retry :("; button "Review Quiz".

Feasibility, Validity, and Practicality Analysis

The feasibility of the SIREMA application was assessed through a rigorous validation process involving subject matter experts and media experts. Three subject matter experts evaluated the application based on content quality, alignment with Problem-Based Learning (PBL) syntax, and cognitive learning indicators. According to Risdianto et al. (2022), rigorous validation testing ensures that learning media applications are effective, accurate, and appropriate for educational use before implementation. This process identifies deficiencies in content, design, or functionality early on, preventing ineffective tools from reaching students and wasting resources (Azrillia et al., 2024). The analysis revealed that the application achieved an average validation score of 99.1%, categorizing it as "Very Feasible". Specifically, the content aspect achieved a perfect score of 100%, indicating that the biological concepts presented are accurate and highly relevant to the curriculum, while the methodological aspect scored 86.7%.

In terms of media design, two experts evaluated the application's interface, navigation, and visual assets. Media validation resulted in an average score of 84.4%, falling into the "Very Feasible" category. The experts highlighted that the visual layout and the integration of 3D animations were particularly effective in engaging students. According to Azrillia et al. (2024), subject matter experts validate content accuracy, relevance, and alignment with curriculum standards, bridging theoretical knowledge to practical application. Their review confirms that the material reflects current industry practices and real-world scenarios, enhancing credibility and learner trust. Table 2 summarizes the expert validation results.

Table 2. Recapitulation of expert validation results

No.	Validator Type	Total Score Obtained	Validity Percentage (%)	Category
1.	Material Experts	223	99,1%	Very Feasible
2.	Media Experts	135	84,4%	Very Feasible

a Source: Primary Data Analysis, 2025

To assess the application's content validity from a practitioner's perspective, we conducted a validation test with five biology teachers from different schools. The data were analyzed using the Content Validity Ratio (CVR) and Content Validity Index (CVI). The calculation yielded a CVI score of 1.00, indicating that the application is "Very Relevant" and meets teachers' instructional needs. The teachers verified that the PBL features in SIREMA effectively guide students through scientific inquiry processes. Masuwai et al. (2024) explain the benefits of the Content Validity Ratio (CVR) and Content Validity Index (CVI), which provide quantitative measures to assess how well a research instrument represents the intended construct through expert judgment.

Furthermore, the practicality of SIREMA was also measured through student responses during the limited trial with 36 Grade XI students. The results showed an overwhelmingly positive response across all assessed criteria. The "Media" aspect received the highest rating of 99%, suggesting that students found the interactive visuals and animations highly appealing. This was followed by the "Practicality" aspect at 98%, indicating ease of use, and the "Material" aspect at 96%, reflecting clarity in content delivery. The detailed student response data can be seen in Table 3.

Table 3. Student response to SIREMA application

Aspect	Indicators		
	Practicality	**Material**	**Media**
Total score	392	173	143
Percentage (%)	98%	96%	99%
Criteria	Very good	Very good	Very good

a Source: Primary Data Analysis, 2025

These high scores in feasibility, validity, and practicality demonstrate that SIREMA is a robust educational tool. The integration of multimedia elements such as text entry, interactive markers, and gamified quizzes not only attracts students' attention but also reduces the barrier to understanding complex physiological mechanisms, as supported by the positive feedback from both experts and users. According to Masuwai et al. (2024), using CVR and CVI together provides a rigorous, complementary analysis: CVR pinpoints item-level strengths while CVI verifies overall instrument quality, enhancing credibility and reliability in validation. This approach supports accurate decision-making in tool development, such as questionnaires for science education research.

Effectiveness on Cognitive Learning Outcomes

The effectiveness of the SIREMA application in improving students' cognitive skills was measured through a pretest and posttest administered to 36 students in the experimental class. The descriptive analysis revealed a substantial increase in learning outcomes after the intervention. The average pretest score was 75.6, while the posttest score increased significantly to 97.4, a difference of 21.8 points. This improvement indicates that the application effectively helped students master the concept of the human excretory system, which was initially identified as difficult and abstract.

To quantify this improvement, we calculated the Normalized Gain (N-Gain). The analysis yielded an average N-Gain score of 0.88, which is categorized as High. We also analyzed the distribution of N-Gain scores among students to ensure equitable improvement across the class. The results showed that 80.60% of students (29 students) achieved an N-Gain

in the "High" category, 16.70% (6 students) in the "Medium" category, and only 2.80% (1 student) in the "Low" category. This distribution is visually represented in Figure 5.

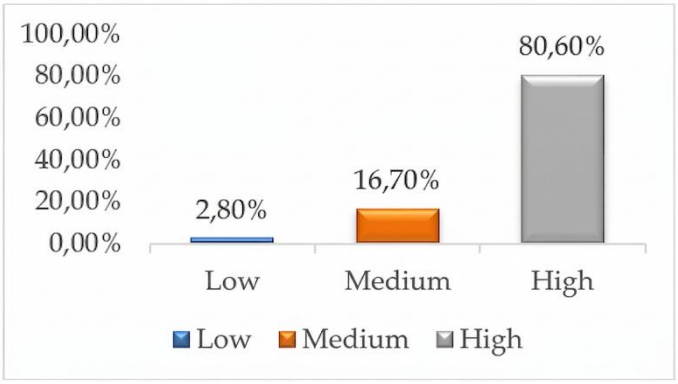

Figure 5. Distribution of students' n-gain scores based on improvement criteria

Before conducting hypothesis testing, we performed prerequisite tests. The Kolmogorov-Smirnov normality test indicated that the pretest data were normally distributed (Sig. 0.186 > 0.05), but the posttest data were not normally distributed (Sig. 0.450 < 0.05). The homogeneity test showed that the data variance was homogeneous (Sig. 0.094 > 0.05). Implications for Hypothesis Testing, according to Ghasemi & Zahediasl, (2012), are that if one dataset (posttest) is not normally distributed, non-parametric alternatives (such as Mann-Whitney U or Wilcoxon tests) are recommended, as these do not require the normality assumption.

Because the posttest data were not normally distributed, the hypothesis was tested using the non-parametric Wilcoxon Signed-Rank Test. The test results yielded an Asymp. Sig. (2-tailed) value of 0.000, which is smaller than the significance level of 0.05 ($p < 0.05$). According to EZSpss (2024) this suggests a statistically significant difference in posttest scores before and after the treatment or intervention. Consequently, the null hypothesis (H0) is rejected, and the alternative hypothesis (Ha) is accepted. This confirms a statistically significant difference between pretest and posttest scores, showing that the use of the SIREMA application significantly influences students' cognitive learning outcomes. Several studies in biology and science education, such as Jeno et al. (2017), confirm statistically significant differences between pretest and posttest scores, demonstrating that mobile applications or e-learning tools enhance students' cognitive learning outcomes. Table 4 summarizes the statistical analysis.

Table 4. Summary of statistical analysis on cognitive learning outcomes

Statistical Parameter	Value	Criteria / Interpretation
N-Gain Score	0.88	High Category
Normality (Posttest)	0.000	Not Normal
Wilcoxon Test (Sig.)	0.000	Significant Difference
Pretest Mean	75.6	-
Posttest Mean	97.4	-

a Source: Primary Data Analysis, 2025

The significant improvement in cognitive outcomes can be attributed to several key features of the SIREMA application. First, integrating multimedia elements (3D animations and videos) helped visualize abstract physiological processes, such as urine formation in the kidneys, which students previously found difficult to understand through text alone. This

aligns with Mayer (2009) cognitive theory of multimedia learning, where dual-channel processing (visual and verbal) reduces cognitive load. Over 90% of users rated the research by Nakhoul et al. (2024) as user-friendly, engaging, and superior for understanding 3D structures, with focus groups highlighting improved recall as a "memory anchor" for clinical scenarios.

Second, the Problem-Based Learning (PBL) syntax embedded in the app played a crucial role. The “Orientation to Problem” and "Investigation" features shifted the students' role from passive recipients to active problem solvers. By engaging in independent investigation using the interactive markers, students were able to construct their own understanding, leading to higher retention and mastery of concepts. This supports the researchers' finding that Android-based media integrated with PBL is effective in enhancing students' critical thinking and cognitive achievements. Nurwidodo et al. (2025) state that this initial phase presents students with an open-ended problem or scenario, prompting them to clarify terms, activate prior knowledge, and identify what they need to learn, shifting focus from rote memorization to contextual inquiry.

Conclusion

This study successfully developed an Android-based biology learning medium (SIREMA) focused on the human excretory system using the ADDIE model stages. Based on the validation results, the application was declared "Very Feasible," achieving scores of 99.1% from material experts and 84.4% from media experts. Educational practitioner assessments (using CVR and CVI techniques) also confirmed the content validity of the medium, and positive student responses further supported its practicality in classroom use, with the highest percentage reaching 99%. The application proved effective in significantly improving cognitive learning outcomes (Wilcoxon test, $p < 0.05$), as shown by an increase in the average score from 75.6 (pretest) to 97.4 (posttest). This improvement was corroborated by an N-Gain score of 0.88 (High category), with 80.60% of students meeting the high criteria. Although there were technical adaptation challenges during initial use, the application was rated excellent for its visuals and ease of operation, making it suitable for supporting independent learning.

Acknowledgement

I extend my sincerest gratitude to the Head of the Department and the Lecturers of the Biology Education Study Program at UIN Siber Syekh Nurjati Cirebon for their guidance in completing this research, titled The Development of the Problem-Oriented Android Application for Learning the Human Excretory System for Eleventh Grade High School.

Generative AI Disclosure

The use of artificial intelligence was utilized in two aspects of this research. First, AI-generated computer audio was integrated into the development of the SIREMA app. Second, Grammarly was used to improve the grammar, clarity, and academic tone of the manuscript. The use of these tools did not alter the scientific substance, data analysis, or primary conclusions of this study.

References

Afrianti, R., & Maryatun, I. B. (2025). Utilization of educational games as learning media: recognize the concept of numbers-noncommercial-sharealike 4.0 international license (CC BY-NC-SA 4.0). *Jurnal Eduscience (JES)*, *12*(2), 592–604. https://doi.org/10.36987/jes.v12i2.6833

Agustini, I. N., Sa'adah, S., & Paujiah, E. (2021). Digital comics learning media for high school on the human excretory system concept. *Research and Development in Education (RaDEn), 1*(2), 71-85. https://doi.org/10.22219/raden.v1i2.18911

Amir, D., & Lubis, S. P. W. (2025). Penerapan media articulate storyline 3 sebagai pembelajaran interaktif pada materi sistem peredaran darah. *Jurnal Dedikasi Pendidikan, 9*(1), 453–466. https://doi.org/10.30601/dedikasi.v9i1.5809

Andariana, A., Zubaidah, S., Mahanal, S., & Suarsini, E. (2020). Identification of biology students' misconceptions in human anatomy and physiology course through three-tier diagnostic test. *Journal for the Education of Gifted Young Scientists, 8*(3), 1071–1085. https://doi.org/10.17478/jegys.752438

Anggraeni, D. M., Prahani, B. K., Suprapto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic review of problem-based learning research in fostering critical thinking skills. *Thinking Skills and Creativity, 49*, 101334. https://doi.org/10.1016/j.tsc.2023.101334

Auliyani, C. N., Arianto, F., & Kholidya, C. F. (2025). A systematic literature review of project-based learning integrated with STEM education: examining implementation strategies, outcomes, and challenges. *Jurnal Visi Ilmu Pendidikan, 17*(1), 214–231. https://doi.org/10.26418/jvip.v17i1.85610

Azrillia, W., Oktaviyanthi, R., Khotimah, K., & Garcia, M. L. B. (2024). Feasibility test of articulate storyline 3 learning media based on local wisdom for optimizing students' algebraic thinking skills. *Paedagogia, 27*(1), 1. https://doi.org/10.20961/paedagogia.v27i1.84145

Bonita, T., Masitah, Jailani, & Nasution, R. (2024). Misconception analysis using three-tier multiple choice diagnostic test assisted by google form on excretory system material class XI Students at SMAN 16 Samarinda. *Biosel Biology Science and Education, 13*(2), 150–159. https://doi.org/10.33477/bs.v13i2.7253

Cezar, B. G. da S., & Maçada, A. C. G. (2023). Cognitive overload, anxiety, cognitive fatigue, avoidance behavior and data literacy in big data environments. *Information Processing & Management, 60*(6), 103482. https://doi.org/10.1016/j.ipm.2023.103482

Din-Yan, Y. (1998). Alternative conceptions on excretion and implications for teaching. *Chinese University Education Journal, 26*(I), 101–116.

Ghani, A. S. A., Rahim, A. F. A., Yusoff, M. S. B., & Hadie, S. N. H. (2021). Effective learning behavior in problem-based learning: A scoping review. *Medical Science Educator, 31*(3), 1199–1211. https://doi.org/10.1007/s40670-021-01292-0

Ghasemi, A., & Zahediasl, S. (2012). Normality tests for statistical analysis: a guide for non-statisticians. *International Journal of Endocrinology and Metabolism, 10*(2), 486–489. https://doi.org/10.5812/ijem.3505

Haka, N. B., Fitriani, Y., Solviana, M. D., & Rakhmawati, I. (2025). Interactive e-modules with hologram and text-to-speech: An innovative media for teaching the human excretory system. *Al Jahiz: Journal of Biology Education Research, 6*(1), 15-35. https://doi.org/10.32332/al-jahiz.v6i1.9946

Ilma, S., Al-Muhdhar, M. H. I., Rohman, F., & Saptasari, M. (2020). The correlation between science process skills and biology cognitive learning outcome of senior high school students. *JPBI (Jurnal Pendidikan Biologi Indonesia), 6*(1), 55–64. https://doi.org/10.22219/jpbi.v6i1.10794

Jeno, L. M., Grytnes, J.-A., & Vandvik, V. (2017). The effect of a mobile-application tool on biology students' motivation and achievement in species identification: A Self-Determination Theory perspective. *Computers & Education, 107*, 1–12. https://doi.org/10.1016/j.compedu.2016.12.011

Kasuga, W., Maro, W., & Pangani, I. (2022). Effect of problem-based learning approach on developing students' science process skills on the topic of safety in our environment. *Journal of Turkish Science Education, 19*(3), 872–886. https://doi.org/10.36681/tused.2022.154

Masuwai, A., Zulkifli, H., & Hamzah, M. I. (2024). Evaluation of content validity and face validity of secondary school Islamic education teacher self-assessment instrument. *Cogent Education, 11*(1). https://doi.org/10.1080/2331186X.2024.2308410

Mayer, R. E. (2009). *Multimedia learning (2nd ed.)*. Cambridge University Press.

Muninda, Y. S., Pantiwati, Y., Purwanti, E., & Permana, T. I. (2021). "Liver as excretory organ": Developing Android-based flash learning media for middle school students. *Research and Development in Education (RaDEn), 1*(2), 86-97. https://doi.org/10.22219/raden.v1i2.19033

Mutiara, E., Suyanto, S., B, N. K. L., Laksita, G. D., & Zamzami, Z. (2024). Improving critical thinking skills using problem-based learning: systematic literature review. *Jurnal Penelitian Pendidikan IPA, 10*(12), 988–995. https://doi.org/10.29303/jppipa.v10i12.7872

Nakhoul, G. N., Taliercio, J. J., Bassil, E. H., Arrigain, S., Schold, J. D., Wardrop, R., O'Toole, J., Nally, J. V, Bierer, S. B., Sedor, J. R., & Mehdi, A. (2024). Virtual nephron: Evaluation of a novel virtual reality educational tool. *Kidney International Reports, 9*(9), 2619–2626. https://doi.org/10.1016/j.ekir.2024.06.007

Ngandoh, S. T., Riandi, R., Rahmat, A., & Muslim, M. (2025). Artificial intelligence-integrated interactive multimedia to improve conceptual understanding in eighth-grade science learning. *SciEnggJ, 18*(Supplement), 219–224. https://doi.org/10.54645/202518SupLQR-24

Nurdin, A. M., Gofur, A., Sapta Sari, M., & Munzil, M. (2025). Technology-supported differentiated biology education: Trends, methods, content, and impacts. *Eurasia Journal of Mathematics, Science and Technology Education, 21*(3), em2598. https://doi.org/10.29333/ejmste/16044

Nurhasanah, M., Suprapto, P. K., & Ardiansyah, R. (2024). The effectiveness of problem-based learning assisted by articulate storyline interactive students' critical thinking skills. *Jurnal Inovasi Pendidikan IPA, 10*(1), 1–9. https://doi.org/10.21831/jipi.v10i1.64847

Nurwidodo, N., Zaenab, S., Hindun, I., & Wahyuni, S. (2025). Development of problem orientation model and work organization in problem-based learning at Muhammadiyah Senior High School of Batu city. *JPBI (Jurnal Pendidikan Biologi Indonesia), 11*(1), 424–437. https://doi.org/10.22219/jpbi.v11i1.40190

Prasetyo, I., Rofieq, A., Sukarsono, S., & Permana, T. I. (2022). How kidneys work? Developing of Android-based Adobe animate media for senior high school students. *Research and Development in Education (RaDEn), 2*(1), 19-32. https://doi.org/10.22219/raden.v2i1.20378

Raistanto, W. S. S., Sari, D. K., & Usman, A. (2024). Learning outcomes and reading literacy improvements through the android application "My Biotech" on Biology technology innovation material. Biosfer: *Jurnal Tadris Biologi, 14*(2), 205. https://doi.org/10.24042/biosfer.v14i2.17008

Risdianto, E., Wachidi, W., Riyanto, R., Fathurochman, I., Yanto, M., & Asmara, A. (2022). Feasibility test of learning media with blended learning model and augmented reality-assisted MOOCs. *Jurnal Ilmiah Peuradeun, 10*(1), 149–164. https://doi.org/10.26811/peuradeun.v10i1.626

Ristanto, R., Rahayu, S., & Mutmainah, S. (2021). Conceptual understanding of excretory system: implementing cooperative integrated reading and composition based on scientific approach. *Participatory Educational Research, 8*(1), 28–47. https://doi.org/10.17275/per.21.2.8.1

Riyanto, F., Miranto, S., & Noor, M. F. (2024). The development of an interactive biology e-module based on articulate storyline for class XI digestive system concepts. *International Journal of Learning Media on Natural Science (IJLENS), 1*(1), 14–19. https://doi.org/10.60005/ijlens.v1i1.20

Rizalia, S., Nopriansyah, S., Saefi, M., Adi, W. C., Damayanti, E., & Sukmawati, S. (2024). Students' learning difficulties based on cognitive level of excretory system material. *JPBI (Jurnal Pendidikan Biologi Indonesia), 10*(2), 521–530. https://doi.org/10.22219/jpbi.v10i2.32212

Sakti, M. R. B. (2025). Integrating STEM-PBL to improve learning outcomes: a scope review. *Jurnal Edukasi dan Multimedia, 2*(1), 1–11. https://doi.org/10.37817/jurnaledukasidanmultimedia.v2i1.4724

Sangur, K., Zubaidah, S., & Sulisetijono. (2025). A systematic literature review of mobile learning trends in biology education over ten years. *Social Sciences & Humanities Open, 11*, 101429. https://doi.org/10.1016/j.ssaho.2025.101429

Sihotang, Y. L. T., Sukardiyono, & Heru Kuswanto. (2025). Effects problem solving skills in school learning: Systematic literature review. Indonesian Journal of Educational Research and Review, 8(1), 70–79. https://doi.org/10.23887/ijerr.v8i1.87593

Usman, A., Munandar, K., & Utomo, A. P. (2024). How can PBL promote critical thinking skills in biology material? A systematic literature review in reputable journals. *Research and Development in Education (RaDEn), 4*(1), 450–464. https://doi.org/10.22219/raden.v4i1.32401

Wahdaniyah, N., Agustini, R., & Tukiran, T. (2023). Analysis of effectiveness PBL-STEM to improve student's critical thinking skills. *IJORER: International Journal of Recent Educational Research, 4*(3), 365–382. https://doi.org/10.46245/ijorer.v4i3.312

Yusuf, M. H., Musa, D., Abdullahi, A., & Dede, A. M. (2025). Exploring AI-driven personalized learning platforms for adapting biology curricula based on student performance. *Faculty of Natural and Applied Sciences Journal of Computing and Applications, 2*(3), 43–51. https://doi.org/10.63561/jca.v2i3.835