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Gamified web-based learning to improve evaluation skills in teacher professional education courses

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ABSTRACT

Education is a key pillar in the development of individuals and society. In this digital era, technology has revolutionized learning by expanding access and improving the quality of the learning process. One of the recent innovations is the use of web-based learning (WBL), which, although flexible, often lacks interaction elements, thus reducing user engagement. To address this, this research proposes a platform, “Meja Guru Academy,” that integrates gamification elements in WBL to improve the learning evaluation skills of Teacher Professional Education (PPG) students. This research utilizes the Design Thinking approach, which involves the stages of empathy, problem definition, idea development, prototyping, and evaluation—the data collection method through questionnaires produced quantitative and qualitative data for system validation. Content experts rated the platform's educational material at 85.33%, indicating exceptional alignment with learning objectives, while media experts provided a score of 89.60%, highlighting effective usability. User testing with PPG students yielded a strong System Usability Scale (SUS) score of 79, suggesting the platform is highly user-friendly. Additionally, the User Experience Questionnaire (UEQ) results indicated positive user perceptions across multiple aspects, with high ratings in pragmatic quality attributes such as perspicuity and efficiency, and hedonic qualities including stimulation and novelty. Overall, Meja Guru Academy presents an innovative and effective solution for advancing PPG students' evaluation competencies, fostering engagement and self-directed learning through gamified WBL.



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INTRODUCTION

In the digital age, the rapid advancement of technology has significantly transformed the landscape of education, providing new opportunities for enhancing the learning process. One notable innovation is web-based learning (WBL), which offers students flexible access to educational content, including text, images, animations, audio, and video. Despite its advantages, a major challenge in WBL platforms is maintaining student engagement and activity levels. Learners often

experience low interactivity and limited motivation, particularly when the platform only serves as a passive information delivery system without incorporating dynamic and interactive elements (Dichev & Dicheva, 2017). Addressing this challenge is critical, especially in higher education settings where active participation plays a pivotal role in shaping learning outcomes.

To overcome this issue, gamification has emerged as an effective strategy that enhances WBL by integrating game-like elements to foster student engagement and success. Gamification refers to the application of game design components such as points, badges, leaderboards, challenges, and narrative-driven experiences into non-game contexts like education. Research has shown that incorporating gamification in online learning environments can significantly improve student learning outcomes. For instance, Aljraiwi (2019) demonstrated that students exposed to gamified learning environments outperformed those in conventional settings by an average difference of 5.4 points on academic tests. Furthermore, gamification not only enhances motivation but also creates a more interactive and emotionally engaging learning experience, particularly when combined with immediate feedback and storytelling elements (Huang & Wang, 2025).

In addition to addressing motivational challenges, gamification aligns with the ongoing shift in educational paradigms, which emphasizes the development of essential skills beyond factual knowledge acquisition. Modern education increasingly prioritizes critical skills such as learning evaluation, which are vital for assessing knowledge comprehension and fostering lifelong learning (Cetin et al., 2023; Fatima & Sme, 2023). In this context, the Professional Teacher Education (PPG) program serves as a pivotal initiative aimed at preparing prospective teachers to become competent educators. The PPG program emphasizes the mastery of learning evaluation skills, which are essential for designing and implementing effective assessments. However, many PPG students struggle to develop these skills due to limited exposure to diverse assessment methods and insufficient practical training opportunities (Sari et al., 2023).

To address these gaps, the “Meja Guru Academy” platform has been designed as a gamified web-based learning environment that supports PPG students in developing their learning evaluation skills. The platform introduces interactive challenges, scenario-based assessments, and reflective activities tailored to the domains of teaching and assessment. By integrating gamification elements such as points, badges, leaderboards, and real-time feedback, “Meja Guru Academy” aims to create an engaging and motivating learning experience. What sets this platform apart is its emphasis on experiential learning, where users are actively involved in applying theoretical knowledge to practical assessment scenarios. This unique approach not only enhances student engagement but also fosters a deeper understanding of learning evaluation concepts.

The integration of gamification into teacher training programs represents a promising strategy for improving both teaching quality and student outcomes. Effective use of educational technology by teachers can significantly increase students' interest in learning (Indriyansyah et al., 2023). By leveraging gamification, “Meja Guru Academy” aspires to bridge the gap between theory and practice, equipping future educators with the skills necessary to design and implement high-quality learning assessments. This platform represents a significant step toward creating a more interactive, engaging, and effective teacher training experience that aligns with the evolving demands of modern education. This study aims to evaluate the results of the development of Meja Guru Academy in terms of material quality, media display, and usability. This is very important to ensure the acceptance of the platform by PPG students so that it can stimulate motivation and improve Learning Evaluation Skills.

METHOD

This study adopts the Design Thinking model, a user-centered approach aimed at understanding user experiences, pinpointing challenges, and developing innovative ideas to design features that align with user needs and preferences (Saefudin et al., 2023; Wira et al., 2024). The Design Thinking model includes five stages: Empathize, Define, Ideate, Prototype, and Test.

1. Empathize

The initial stage of Design Thinking, known as Empathize, focuses on building empathy to thoroughly understand the issues requiring solutions. This user-centered approach allows

researchers to set aside personal biases and gain a clear understanding of user needs. During this phase, data collection is conducted by exploring user challenges, often through interviews. The insights gathered in this phase serve as the foundation for identifying key user requirements, which later become the basis for designing the system's initial features and evaluation criteria.

2. Define

The second stage of Design Thinking, called the Define phase, concentrates on clearly identifying the main problem based on observations of users. As noted by [Kuzmina & Pavlovskaya \(2024\)](#), this phase involves gathering key information about the features and functionalities users need, which is crucial for designing an effective system. By synthesizing insights gathered during the Empathize phase and gaining an in-depth understanding of the user experience, designers are better equipped to precisely outline the issues that need to be addressed. The outcomes of this stage significantly influence the design framework and serve as the basis for formulating the questionnaire items used in the SUS and UEQ testing methods to evaluate usability and user experience.

3. Ideate

The ideation stage is essential for discovering creative solutions and examining different viewpoints on the problem at hand. By brainstorming, a wide range of ideas is generated, serving as the groundwork for system development and often leading to the creation of low-fidelity prototypes or wireframes. This adaptable approach aligns well with evolving trends and user demands, making it a favored method in design fields for encouraging innovative and relevant solutions ([Dewi et al., 2024](#)). The selected ideas are translated into system features that directly address the problems defined in the previous stage. These features are later tested through the Likert scale method to assess their perceived usefulness and functionality.

4. Prototype

In this phase, the ideas and concepts generated during brainstorming are brought to life through a test application or product. This involves building prototypes intended for direct user interaction, typically as mockups or high-resolution prototypes that offer a closer representation of the actual user experience. The initial prototypes undergo expert validation from media experts and subject matter experts, who provide qualitative feedback on the interface design and content quality. This feedback is used to refine the prototype before testing with users.

5. Test

At this stage, the product is implemented and validated by media experts and subject matter experts. The media experts evaluate the media development, while the subject matter experts assess the learning content, specifically for the course on Principles of Teaching and Assessment. The product trial involves PPG students from Universitas Negeri Malang who are studying the Principles of Teaching and Assessment course. The user experience is measured using the System Usability Scale (SUS) to evaluate overall usability, the User Experience Questionnaire (UEQ) to assess the user experience, and the Likert scale to measure user satisfaction regarding the platform's usefulness. Feedback gathered during this phase serves as an essential reference for further prototype improvements, completing the iterative process of Design Thinking.

In developing the learning materials for PPG students at Universitas Negeri Malang, several tests were conducted to ensure the quality and effectiveness of the content. The research was carried out at Universitas Negeri Malang. Expert testing involved two content experts and three media experts who assessed the accuracy of the content and the suitability of the media. User testing involved 30 PPG students from Universitas Negeri Malang, class of 2024, to evaluate user responses to the material. This testing aimed to identify strengths and weaknesses and guide improvements in alignment with student needs and learning standards.

The primary feature evaluated in this study is gamification embedded within the provided learning materials. The gamification elements include interactive quizzes, point-based rewards, and progress tracking, designed to increase student engagement and motivation during the learning process.

This research uses a Likert scale-based questionnaire to measure satisfaction or suitability, with scores ranging from 5 for "Very Good/Suitable" to 1 for "Not Good," to standardize the statistical data analysis (Kusmaryono et al., 2022). The five variables analyzed include interviews for qualitative data related to needs analysis, as well as media and content expert validation using interval-scaled questionnaires, which produce both quantitative and qualitative data.

User testing used the System Usability Scale (SUS), the most widely used standardized questionnaire for assessing perceived usability. This review of SUS covers its early history from its inception in the 1980s through recent research and its prospects (Lewis, 2018). Using the User Experience Questionnaire (UEQ) for user testing. The User Experience Questionnaire (UEQ) method is used as a testing method using six assessment scales, namely attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty, which have aesthetic and functional quality evaluation aspects (Maulidya et al., 2024).

This study collected both quantitative and qualitative data. The quantitative data, represented numerically, were gathered from questionnaires completed by participants (Randi & Corno, 2022). In contrast, the qualitative data included textual information, descriptive words, and images derived from feedback, critiques, comments, and interviews with media and content experts concerning the product's feasibility.

Data analysis was carried out by calculating the average score and percentage for each aspect of the assessment, as well as calculating the total score and overall percentage. After the data was collected, to evaluate the weight of each response and calculate the average score, the following is an example of Formula 1:

$$\tilde{x} = \frac{\sum x}{n} \quad (1)$$

Description:

$\tilde{x}$ = Average Score
 $\sum x$ = Number of Appraisers
 n = Total Score for Each

Then, for the percentage formula, the result can be calculated with the following Formula 2:

$$Total\ Score = \frac{Total\ Value}{Max\ Score} \times 100\% \quad (2)$$

The processed data results will be evaluated against media feasibility criteria, as adapted from (Vicente & Camocho, 2024) and shown in Table 1. The media feasibility criteria are assessed based on six aspects: Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation, and Novelty. These aspects represent key dimensions of user experience and media quality, which play a crucial role in determining the platform's overall feasibility. However, the specific connection between each aspect and the final media feasibility score should be explicitly explained to provide a more comprehensive understanding of the evaluation process.

Table 1. Media Feasibility Criteria

No.	Percentage (%)	Feasibility Level	Description
1	90% - 100%	Very Good	Very good and no need for revision
2	75% - 89%	Good	Feasible and needs little revision
3	65% - 74%	Fair	Less feasible and revised sufficiently
4	55% - 64%	Not Good	Not feasible and needs more revision
5	0% - 54%	Very Not Good	Not suitable for use and needs revision

In this data collection process, researchers used questionnaires to collect feedback from experts and users. A total of two material experts and three media experts participated to evaluate the validity of the gamified quiz website, focusing on the feasibility of content, interface, and effectiveness of learning media. In addition, a SUS test was also conducted to obtain direct responses from PPG students at Universitas Negeri Malang, involving 30 students as samples.

RESULTS AND DISCUSSION

This study employed the Design Thinking model, which consists of five stages: Empathize, Define, Ideate, Prototype, and Test, to develop and evaluate the Meja Guru Academy platform as a gamified web-based learning tool for PPG students. Through a combination of expert validation, user testing, and standardized usability assessments, the effectiveness of the platform was examined. The following section discusses the detailed findings and their implications.

Results

Meja Guru Academy platform, aimed at enhancing professional educators' competencies with a focus on teaching principles and assessment practices for vocational high schools.



Figure 1. Landing Page

Here is the overview of the landing page Meja Guru Academy website, as shown in Figure 1. There is a landing overview and a login button for the user. Each new user can register an account on the login page to access the features.



Figure 2. Dashboard Page

The dashboard page in Figure 2 displays the dashboard overview, motivational banner, material section, points and progress tracking, and the leaderboard. The material section shows learning topics with progress indicators, while points and progress tracking display accumulated points. The leaderboard ranks users by points, fostering competition and motivation through gamification.

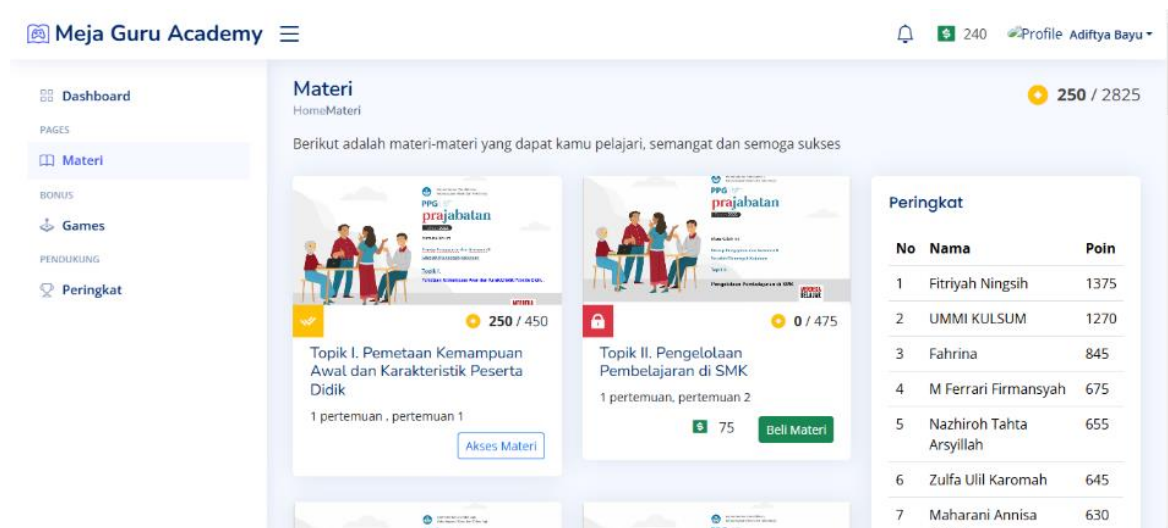


Figure 3. Material Page

The Material Page shown in Figure 3 provides an organized view of available learning resources for students on the Meja Guru Academy platform. The first material is free to open and get points by completing the material. Students must purchase the next material from the points earned to gain access. On this page also displays the leaderboard.

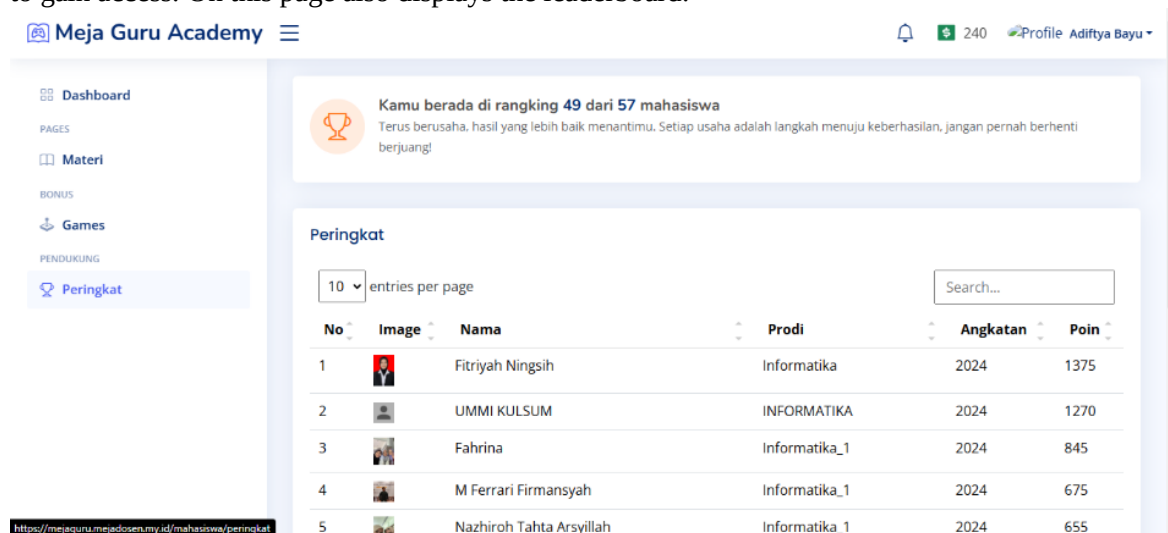


Figure 4. Leaderboard Page

Figure 4 shows the Meja Guru Academy platform leaderboard, displaying student rankings by name, study program, class, and total points earned from completing the task in the material page.

The validation results from the material experts include an assessment from a lecturer of Electrical Engineering and Informatics at Universitas Negeri Malang. This analysis provides important insights regarding the quality of the material and the relevance of the website as a learning medium. Details of the results of this validation are presented in Table 2 below.

Table 2. Meja Guru Academy Material Validation Data

No.	Aspect	Score	Max Score	Validation (%)	Criteria
1.	Content	13	15	86.67	Good
2.	Language	13	15	86.67	Good
3.	Presentation	22	25	88.00	Good
4.	Evaluation	16	20	80.00	Good
Total		64	75	85.33	Good

Table 2 demonstrates that the Meja Guru Academy materials developed for the “Principles of Teaching and Assessment II in Vocational High Schools” course for PPG students meet the validation criteria exceptionally well, achieving a total validation score of 85.33%, which falls within the good category.

The results of validation by media experts conducted by lecturers of Electrical Engineering and Informatics at the Universitas Negeri Malang, and one teacher who has experience teaching PPG Students, which can be seen in Table 3.

Table 3. Meja Guru Academy Media Validation Data

No.	Aspect	Score	Max Score	Validation (%)	Criteria
1.	Attractiveness	13	15	86.67	Good
2.	Perspicuity	27	30	90.00	Very Good
3.	Efficiency	19	20	95.00	Very Good
4.	Dependability	23	25	92.00	Very Good
5.	Stimulation	14	15	93.33	Very Good
6.	Novelty	16	20	80.00	Good
Total		112	125	89.60	Good

As shown in Table 3, the Meja Guru Academy media on the developed website meets a high standard, with a total media validation score of 89.60%, categorized as good. The score indicates that the gamified website media is suitable for use and ready for the trial stage.

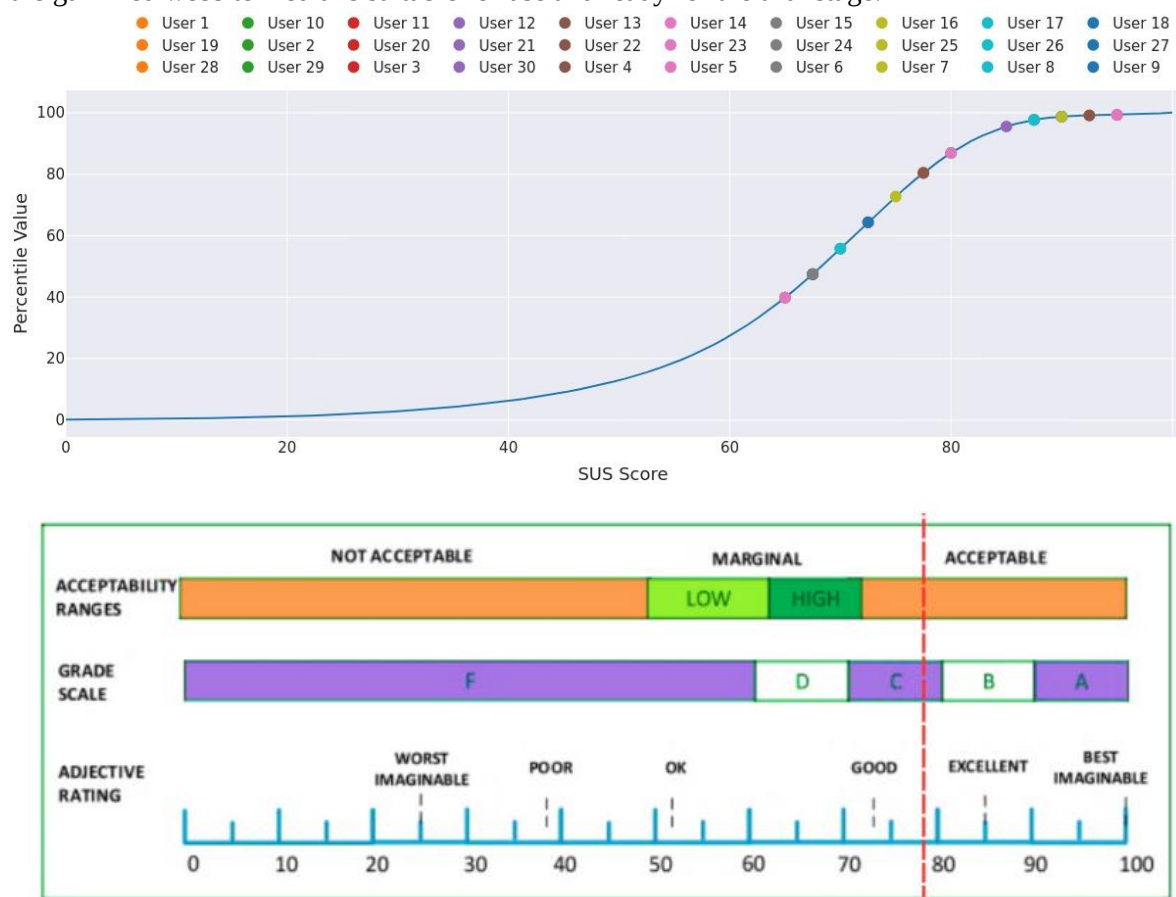


Figure 5. SUS Score Diagram

Based on the results from the System Usability Scale (SUS) testing presented in Figure 5, it can be concluded that the average SUS score across 30 respondents is 79. This score indicates that the system is rated well in terms of usability and is generally perceived as user-friendly and effective. According to SUS interpretation guidelines, scores between 70 and 80 are considered "Good," while

scores above 80 are in the "Excellent" range. Therefore, with an average score of 79, this system is close to the excellent threshold, suggesting that users find it easy to use and functional.

And based on the SUS Score Diagram result in Figure 5. shows a range of user scores from low (around 20) to high (near 100), with most users scoring above 60, indicating generally positive usability feedback. The percentile axis reveals that users with scores below 40 fall in the lower percentiles (<25%), while those scoring above 80 are in the top percentiles (>75%), reflecting excellent satisfaction. A SUS score above 68 is typically considered above average. However, some users scored below this threshold, suggesting areas for improvement. Further analysis may help identify specific issues affecting lower-scoring users.

Overall, it can be concluded that the system is well-designed to support its intended purpose, making it suitable for use as a usability-focused learning tool in vocational school environments.

Table 4. UEQ Test Data

No.	Scale	Mean	Comparison to Benchmark	Interpretation
1	Pragmatic Quality	2.175	Excellent	In the range of the 10% best results
2	Hedonic Quality	2.016666667	Excellent	In the range of the 10% best results
3	Overall	2.10	Excellent	In the range of the 10% best results

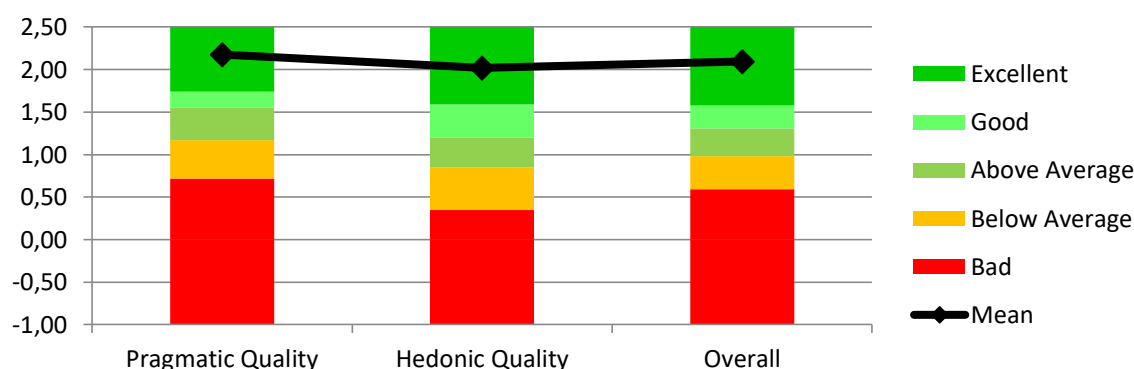


Figure 6. Benchmark UEQ Diagram

Based on Table 4 and Figure 6 results from UEQ testing, suggested that while the system generally has satisfactory usability in terms of pragmatics, there are areas in both pragmatic and hedonic quality that could be enhanced. Improvements in efficiency, clarity, excitement, and innovativeness could lead to a more engaging and effective user experience.

The User Experience Questionnaire (UEQ) results shown in Figure 6 from 30 PPG Student Respondents showed that the pragmatic and hedonic qualities of the platform were rated Excellent, with an overall average score of 2.10. All aspects were within the top 10% of benchmark results, indicating an excellent user experience, both in terms of usability (pragmatic) and emotional satisfaction (hedonic).

Discussion

The use of gamified web-based learning platforms like Meja Guru Academy shows a positive impact on learning motivation and evaluation skills of Teacher Professional Education (PPG) students. The platform's design, aligned with Design Thinking principles, effectively enhances the engagement of learners through interactive elements such as points, leaderboards, and badges (Dichev & Dicheva, 2017). By incorporating gamification into web-based learning, students experienced higher engagement, which is crucial for developing skills necessary for effective teaching and assessment.

Results from the validation of educational content and usability testing, as illustrated in Tables 2 and 3, underscore the platform's effectiveness. The material experts gave a high validation score of 85.33%, with the presentation aspect getting the highest score of 88.00% indicating that the content

is well structured to fulfil the learning objectives. Similarly, the media expert's validation score of 89.60%, with the efficiency apparatus scoring 95.00% made the aspect with the highest score, reflecting the usefulness and attractiveness of the platform in engaging students in learning (Hidayat et al., 2022; Wang et al., 2024).

Pragmatic Quality, with a score of 2.175, rated Excellent, highlights the platform's functionality in helping students achieve their learning objectives effectively. And the Hedonic Quality aspect scored 2.016, assessing the enjoyment and emotional satisfaction gained from using the platform creates a positive user experience, strengthening student engagement.

Moreover, the SUS test results, with an average score of 79 from Figure 5, suggest that users find the platform highly user-friendly. This score places Meja Guru Academy near the threshold of excellent usability, suggesting that students can efficiently navigate the platform, which promotes independent learning. Frequent feedback, coupled with competitive elements, further enhances user engagement and motivation, as observed in the increase in student motivation and learning satisfaction (Huang et al., 2019; Mandouit, 2018).

Despite the positive results, some weaknesses were identified, such as the Novelty Aspect getting a score of 80.00%. Although the platform integrates common gamification features, the lack of innovative elements may limit long-term engagement. Some users scored below 40 on the SUS score, indicating that certain technical aspects or usability issues may hinder the learning experience for a minority of students. Even though the hedonic quality was rated as very good, further improvements in terms of fun and innovative features could increase user enjoyment.

The platform helps PPG students develop essential skills for their future careers, including independent learning habits, mastery of evaluation methods, motivation to engage in continuous professional development, and familiarity with digital learning platforms, which are increasingly used in vocational education settings, as well as motivation through points and leaderboards. The points and leaderboard system utilises both intrinsic and extrinsic motivations, such as students feeling satisfaction for mastering the content and outperforming their previous grades. As well as competitive elements, such as leaderboards, reward high-achieving students with recognition, thus encouraging further participation.

The use of gamification elements in educational contexts effectively enhances student motivation by aligning with Self-Determination Theory (SDT) and other motivational frameworks. The integration of elements such as leaderboards, feedback, and collaborative challenges fosters autonomy, competence, and relatedness, which are crucial for intrinsic motivation. This approach not only engages students but also promotes active learning through interaction and feedback (Deci et al., 2017; Howard et al., 2021).

CONCLUSION

The findings of this study show that the Meja Guru Academy platform, with integrated gamification elements, effectively improves learning motivation and evaluation skills among Teacher Professional Education (PPG) students. The validation results from material and media experts, as well as the high user experience scores (SUS: 79, UEQ: Excellent), indicate that the platform is usable and fits the learning objectives. However, while these validation scores are important, reflective conclusions must go beyond the numerical results to address broader implications.

In a broader educational context, the success of Meja Guru Academy highlights the potential of gamified learning tools in vocational education and teacher training programs. The platform's ability to foster engagement through game mechanics suggests that similar strategies could be applied to other professional learning environments. The integration of points, leaderboards, and challenges not only increases motivation but also aligns with lifelong learning principles, encouraging self-directed skill development. Future research should explore how gamification specifically supports lifelong learning skills, such as critical thinking, adaptability, and self-regulated learning.

While this study provides promising results, it has limitations that must be acknowledged. The relatively small sample size of 30 PPG student respondents from Universitas Negeri Malang means

that the findings may not be generalizable to other contexts. In addition, further validation is needed to assess the scalability, accessibility, and adaptability of this platform to diverse learning styles. Future studies should consider expanding the number of participants and testing the platform in different educational environments to refine its effectiveness.

One promising direction for future development is the incorporation of narrative-based challenges, which could further enhance engagement and provide deeper contextual learning experiences. While the platform already includes gamification elements such as points, leaderboards, progress tracking, and interactive quizzes, the Novelty aspect received a score of 80%, indicating room for innovation. Future iterations could integrate scenario-based assessments or story-driven challenges that align with the Principles of Teaching and Assessment II course to increase immersion. Additionally, while the Hedonic Quality score (2.016) from the UEQ test suggests a positive user experience, further research could examine how narrative elements influence long-term engagement, motivation, and knowledge retention. Testing these features with a larger and more diverse user group could provide valuable insights into optimizing gamified learning environments for teacher training programs.

Finally, the study's methodology was based on the Design Thinking model, but the conclusion does not explicitly tie the findings back to this framework. Future discussions should examine how each stage of Design Thinking (Empathize, Define, Ideate, Prototype, Test) influenced the platform's success and what aspects might still require refinement. In conclusion, Meja Guru Academy demonstrates the potential of gamified web-based learning to enhance teacher training, but further research is needed to explore its long-term impact, address its limitations, and refine its design for wider educational adoption.

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Analyzing students' computational thinking and math reasoning via PISA-based learning

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ABSTRACT

Computational thinking and mathematical reasoning abilities are crucial 21st century skills. However, the results of international studies show that these abilities are still low in Indonesian students. This study aims to test the effectiveness of PISA-based learning in improving the computational thinking and mathematical reasoning abilities of junior high school students. The PISA Principles are a learning guide released by the OECD to produce globally competent students. The study used a quasi-experimental design with two groups of grade VII junior high school students as subjects. The experimental group received a contextual-based PISA principle learning method, while the control group followed the conventional learning method. The research instrument was a computational thinking and mathematical reasoning ability test. Data were analyzed using a two-sample t-test. The results showed that the contextual-based PISA principle learning method was effective in improving students' mathematical reasoning abilities but was less effective for computational thinking abilities. These findings can be a reference in designing mathematics learning relevant to the demands of the 21st century. The recommendation from the results of this study is the need for instrument adaptation to measure the dimensions of computational thinking that are more specific to the four main indicators, namely: decomposition, pattern recognition, abstraction and algorithms.



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INTRODUCTION

The demands of the 21st century require a fundamental transformation in mathematics education, particularly in developing students' computational thinking and mathematical reasoning skills. These abilities are not merely academic competencies but are essential prerequisites for addressing the complexity of an increasingly dynamic global landscape that calls for advanced thinking skills (Grover & Pea, 2018; Weintrop et al., 2016; Csapó & Molnár, 2019). Computational thinking and mathematical reasoning form the foundation of mathematical literacy, enabling students to think logically, systematically, and critically in solving complex problems beyond mere numerical computation (Lockwood et al., 2022; Jeannotte & Keiran, 2017; Benton et al., 2018). However, the current state of mathematics education in Indonesia reveals a considerable gap between potential and actual practice in fostering these abilities.

Computational thinking is a fundamental skill required by all individuals. It encompasses problem-solving, system design, and understanding human behavior by applying core concepts of computer science (Wing, 2006; Kong, 2019; Zhang & Nouri, 2019). It involves decomposing problems into smaller components, identifying key and relevant elements, recognizing patterns, and planning solutions most efficiently (Yadav, 2014; Barr & Stephenson, 2011; Denning, 2017). In mathematics education, computational thinking helps nurture computational competencies and shifts students' perspectives from viewing mathematics solely as finding correct answers to appreciating its complexity and the existence of multiple solutions (Maharani et al., 2020; Shute et al., 2017; Perez-Marin et al., 2020). Supiarmo et al., (2021) outlined the indicators of computational thinking, including: (1) decomposition (interpreting information and simplifying problems, converting verbal to numerical data, identifying relevant formulas); (2) pattern recognition (identifying problems and recognizing potential patterns); (3) abstraction (focusing on essential information and devising problem-solving strategies); and (4) algorithm design (executing problem-solving steps and drawing conclusions).

Despite its importance, computational thinking skills among Indonesian students remain relatively low. A computational thinking assessment by Kamil et al., (2021) revealed substandard performance, with students scoring well below the minimum proficiency threshold (KKM), attaining a maximum score of only 68.75 and an average of 33.25, against a KKM of 79. The lowest performance was noted in pattern recognition, while decomposition was hindered by students' inability to identify given and required information clearly. Similarly, weaknesses in abstraction and algorithmic accuracy were observed (Azizah et al., 2022).

Comparable challenges are reported internationally. In Finland, Kalelioglu et al., (2019) noted difficulties in integrating computational thinking into the curriculum despite its formal inclusion. In the UK, Sentence & Csizmadia (2017) highlighted teachers' struggles to convey computational concepts in mathematical problem-solving. In Singapore, Kong et al., (2020) observed students' difficulties in transferring computational skills across disciplines. In Spain, Roman-Gonzalez et al., (2018) found disparities in computational thinking across socio-economic groups. Similarly, in Brazil, Brackmann et al., (2019) documented students' limited abstraction and algorithm generalization skills both crucial aspects of computational thinking.

Reasoning is a cognitive process used to derive new conclusions from existing information (Wibowo, 2022; Mercier & Sperber, 2017). In the context of mathematics, reasoning is reflected when students engage in questioning and justification by asking: Is it true? How can I be sure? Why is it true? (Brodie et al., 2010; Mata-Pereira & da Ponte, 2017; Reid & Knipping, 2021). Sumarmo (2018) identified several key indicators of mathematical reasoning, including: drawing logical conclusions; providing explanations based on models, facts, and relationships; estimating results and processes; identifying patterns and relationships; formulating and testing conjectures; constructing counterexamples; applying rules of inference and validating arguments; and developing both direct and inductive proofs. Similar emphasis on logical argumentation and justification is echoed (Stylianides, 2016; Herbert et al., 2019).

Global assessments have consistently highlighted Indonesia's poor performance in mathematics. The 2018 PISA results ranked Indonesia 72nd out of 78 countries in mathematical literacy, significantly below the OECD average (OECD, 2019). TIMSS 2019 similarly placed Indonesia 45th out of 58 countries in mathematical proficiency (Mullis et al., 2020). Domestic studies also confirm these findings. Vebrian et al., (2021) reported low achievement across indicators such as conjecturing, mathematical manipulation, and justification, with mastery levels around 42.88% dropping even further for concluding (41.36%). Izzah & Azizah (2019) similarly found that most students' reasoning skills remain in the low or very low category.

Other countries also face similar issues. In Malaysia, Zulnaldi et al., (2020) found challenges in both deductive and inductive reasoning. In South Africa, Venkat et al., (2021) highlighted students' difficulty articulating logical arguments. Turkish students, according to Aydin & Ubuz (2022), struggled particularly in validating mathematical evidence. In the U.S., Thompson et al., (2017) noted challenges in applying quantitative reasoning to non-routine problems. Collectively, these findings suggest a global need to reform pedagogical approaches toward more contextual and adaptive models.

Given the observed deficiencies, there is a pressing need for effective learning models to enhance students' reasoning and computational thinking. In this context, the present study adopts the PISA-based contextual learning model to investigate its potential in addressing these gaps. The research was conducted in a state junior high school in Piyungan, Bantul, Yogyakarta, representative of semi-urban Indonesian schools and their typical educational challenges.

The PISA principle emphasizes four pillars: (1) learning involves not only teachers and students but also broader social and global contexts; (2) learning should address relevant local, global, and intercultural issues through meaningful understanding; (3) teachers play a critical role in designing quality learning experiences, anticipating obstacles, and fostering a global learning environment; (4) students are encouraged to respond adaptively and provide feedback to foster global and intercultural learning (OECD, 2019; Schleicher, 2022). These foundations align with broader goals of building global competencies (Salzer & Roczen, 2018; Care et al., 2018), though implementation results vary across countries depending on local educational readiness (Tan et al., 2021; Meyer & Benavot, 2013). Nilsen (2016) further emphasizes that the successful adoption of PISA principles is contingent upon systemic educational reform.

This study thus proposes the application of the PISA principles as a strategic pedagogical intervention. According to Mansilla & Schleicher (2022), globally competent students must integrate various knowledge domains, employ critical reasoning, and adapt their communication to diverse social contexts. Teachers are tasked with designing engaging, relevant, and effective learning experiences that incorporate real-world, contextual, and cross-cultural issues. This approach does not merely change teaching techniques it embeds contextual, analytical, and problem-solving paradigms within mathematics instruction (Gravemeijer et al., 2017; Schoenfeld, 2016; Lithner, 2017). The effectiveness of this strategy depends on educators' ability to select meaningful issues and align learning objectives with global literacy and reasoning skills.

In this study, the topic of comparative and inverse values was chosen due to its high relevance to daily life and its applicability in various real-world contexts, consistent with PISA principles. This material fosters logical thinking, presents appropriate cognitive challenges, and enables innovative instructional design rooted in contextual learning (Lamon, 2020; Lobato et al., 2021).

The novelty of this research lies in employing PISA principles to develop students' mathematical reasoning and computational thinking holistically, focusing on the formative stage of junior high school where such skills begin to solidify (English & Gainsburg, 2016; Grgurina et al., 2018). The quasi-experimental design enables a systematic and measurable evaluation of pedagogical impact. Compared to prior studies, this research stands out for its structured methodology, comprehensive assessment tools, and orientation toward 21st-century competencies.

Ultimately, this study contributes to the development of innovative, PISA-based instructional models, provides empirical evidence of their effectiveness, and offers a conceptual foundation for mathematics curricula aligned with global standards. As such, it presents both scholarly value and practical solutions for transforming mathematics education in Indonesia to meet international expectations.

METHOD

Research Objectives

This study aims to: 1) examine the influence of the learning method on students' mathematical reasoning and computational thinking abilities; 2) evaluate the effectiveness of the contextual-based PISA principles learning method in enhancing students' mathematical reasoning abilities; 3) evaluate the effectiveness of the contextual-based PISA principles learning method in enhancing students' computational thinking abilities.

Research Subjects

The subjects of this study were 64 seventh-grade students from a public junior high school in Piyungan, Bantul, Yogyakarta Special Region (DI Yogyakarta). The participants were divided into

two groups: 32 students in the experimental group and 32 in the control group. A purposive sampling technique was employed, considering the equivalence of students' initial abilities. The research was conducted during the first semester of the 2023/2024 academic year.

Research Procedure

This study employs a quantitative approach with a quasi-experimental research design. This design was selected because the sample groups used were pre-existing classroom groups formed during regular school activities. The study adopts the Two Equivalent Groups Posttest-Only Design, in which the experimental and control groups are assumed to have equivalent baseline conditions. The research procedure consists of the following stages: 1) preparation and development of research instruments; 2) instrument validation; 3) implementation of learning in the experimental group using context-based PISA principles over six sessions; 4) administration of the post-test; 5) data analysis. The following is the research flow diagram:

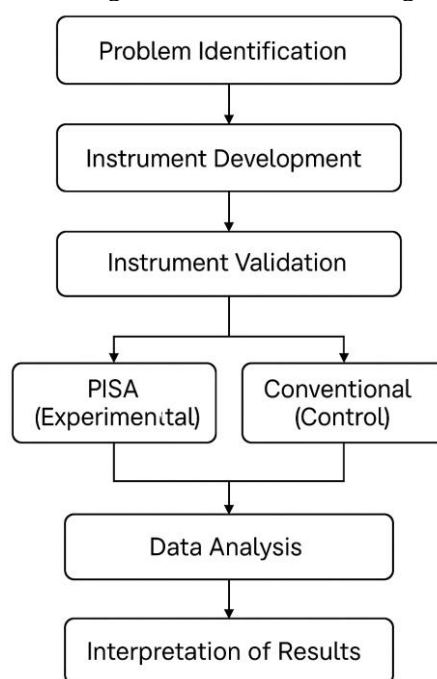


Figure 1. Research Flowchart

Research Data and Instruments

The data collected in this study were in the form of students' mathematical reasoning and computational thinking ability scores. In the computational thinking test, the instrument used was 8 questions with the following grid details:

Table 1. Computational Thinking Test Instrument Grid

Aspects Measured	Indicator	PISA Principles	Question Type	Question Number
Observe patterns and focus on the important information	Students can answer questions related to the application of equivalent comparisons in real-life situations	Involves issues or contexts that are relevant to everyday life, such as the time it takes to fill a bathtub with water, the height of the water in the bathtub, and the relationship between the two, both descriptively and abstractly	Multiple Choice	2
Determine the steps needed to solve a problem.	Students can determine the equivalent comparison codomain values		Multiple Choice	3

Determining what steps are needed to solve a problem	when the domain is known Students can solve problems involving the application of inverse ratios in everyday situations	Involves relevant everyday issues or contexts that may not be familiar to all students, such as the relationship between the number of cows on a farm, the amount of feed, and the time it takes to consume the feed.	Essay	6
Observing patterns and seeing similarities	Students can determine the domain and codomain of inverse comparison values presented in a table.	Involves relevant issues or contexts on a more global scale, such as race tracks and travel time	Table Fill	8
Observing patterns and focusing on important information	Students can draw a graph comparing inverse values		Drawing a Graph	11
Focus on important information.	Students can draw a comparison graph of values	Involves relevant everyday issues or contexts, such as cake making	Drawing a Graph	12
Observing Patterns	Students can draw a comparison graph of values		Identify a Graph	13
Observing patterns	Students can draw a graph comparing inverse values.	Focuses on deep understanding	Identify a Graph	14

The students' mathematical reasoning test consists of 10 questions, with the following detailed grid:

Table 2. Mathematical Reasoning Test Instrument Grid

Aspect Measured	Indicator	PISA Principles	Question Type	Question Number
Drawing Logical Conclusions	Students can comprehend the concept of comparative value	The learning process incorporates issues and contexts relevant to everyday life (such as wage calculation, time required to complete a task, vehicle speed, travel distance, and time allocated for feeding and the number of animals) to address students' learning challenges in understanding the concepts of comparative and inverse values	True / False	1
Estimating Answers and Solution Processes	Students can respond to questions involving the application of equivalent comparisons in real-life situations.		Multiple Choice	2
Using Patterns and Relationships to Analyze	Students can determine the corresponding codomain values in equivalent comparisons	Involving Relevant Everyday Contexts The context involves real-life situations such as the time required to fill a	Multiple Choice	3

Mathematical Situations and Predict Answers and Solution Processes	when the domain values are known.	bathtub with water, the height of the water in the bathtub, and the relationship between these two variables, both descriptively and abstractly.		
Estimating Answers and Solution Processes	Students can determine the equation that represents the relationship between pairs of equivalent comparative quantities.		Multiple Choice	4
Providing Explanations Using Relationships	Students can explain the relationship between pairs of co-varying quantities using clear and coherent written statements.		Multiple Choice	5
Estimating answers and solution processes	Students can answer questions related to the application of inverse ratios in everyday life.		Essay	6
Constructing valid arguments, providing explanations with relationships	Students can understand the concept of inverse value comparisons	Involving relevant issues or contexts from everyday life that may not be familiar to all students, such as the relationship between the number of cows on a farm, the amount of feed, and the time it takes to finish the feed. Deep learning occurs when students can provide appropriate reasoning for the answers they give	Essay	7
Estimating answers and solution processes	Students can solve problems involving the application of inverse ratios in everyday life.		Short Answer Question	9
Estimating answers and solution processes	Students can determine the equation that represents the relationship between pairs of equivalent comparative quantities.		Short Answer Question	10
Students use patterns and relationships to analyze and make sense of mathematical situations.	Students can draw a comparison graph of values	Involves relevant everyday issues or contexts, such as cake making	Drawing a Graph	12

Validity and Reliability of the Instrument

The validity evidence used in this study includes content validity and construct validity. Content validity was established through expert judgment by two experts in the field of mathematics education. The instrument is considered valid if the expert evaluations indicate so. Construct validity was assessed using the point-biserial correlation formula for items with dichotomous scores (0 or 1), and the product-moment correlation formula for essay questions with varying scores.

An item is considered valid if the calculated correlation coefficient (r count) is greater than the critical value from the r table. Based on the validation results, the instrument is considered valid in both content and construct for use with a sample of 64 students. For $N = 64$ at a 5% significance

level, the r table value is 0.24. Content validity was confirmed with revisions, and construct validity was supported as shown in Tables 3 and 4:

Table 3. Construct Validity of Computational Thinking Questions

Number	2	3	6	8	11	12	13	14
r table	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
r hitung	0.57	0.67	0.55	0.50	0.46	0.35	0.43	0.57
	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

Table 4. Construct Validity of Mathematical Reasoning Questions

Number	1	2	3	4	5	6	7	9	10	12
r table	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
r count	0.54	0.47	0.44	0.43	0.43	0.42	0.46	0.51	0.42	0.43
	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

The reliability estimation in this study was conducted using the Cronbach's Alpha formula (alpha coefficient). The instrument is considered reliable if the calculation results show that the r count is greater than the r table value. The following presents the evidence of the reliability of the research instrument:

Table 5. Reliability Estimation

	Mathematical Reasoning	Computational Thinking
r table	0.24	0.24
Alpha Cronbach	0.648	0.622
	Reliable	Reliable

Data Collection Techniques

The data in this study were collected through written tests designed to measure students' mathematical reasoning and computational thinking abilities. The data collection process consisted of the following stages: 1) Developing research instruments for the post-test; 2) Designing the Lesson Plan (RPP) and Student Worksheet (LKS); 3) Validating the instruments and checking their reliability; 4) Revising the instruments based on feedback from expert validators; 5) Conducting the research by administering the treatment to both the experimental and control groups; 6) Administering post-tests to both the experimental and control groups to assess students' mathematical reasoning and computational thinking abilities after the treatment.

Data Analysis Techniques

The data in this study were analyzed using both descriptive and inferential statistical methods. Descriptive analysis was used to describe the results of the learning process based on post-test data on students' mathematical reasoning and computational thinking abilities. The raw scores were converted into a scale ranging from 0 to 100.

Inferential analysis was conducted to generalize findings from the sample to the broader population. The assumption tests included the normality test and the homogeneity test. The normality test used was the Mardia test, which estimates multivariate normality based on skewness and kurtosis. The data are considered multivariate normal if the p -value $> \alpha$ (0.05) in both the skewness and kurtosis tests. The homogeneity of the variance-covariance matrix was tested using the Box's M test. The data are considered homogeneous if the p -value $> \alpha$ (0.05).

Once the assumptions of normality and homogeneity were satisfied, a hypothesis test was conducted using Hotelling's T^2 test to compare the two sample groups. The decision criterion for Hotelling's T^2 test is: H_0 is accepted if the p -value $> \alpha$ (0.05). The hypotheses for this study are as follows:

Table 5. Hypothesis 1

H_0	:	There is no significant effect of learning methods on students' computational thinking and mathematical reasoning abilities.
H_1	:	There is a significant effect of learning methods on students' computational thinking and mathematical reasoning abilities.

To test the effectiveness of the context-based PISA principle learning model on students' computational thinking and mathematical reasoning abilities, a t-test was conducted. The decision criteria for the t-test are as follows: H_0 is rejected if the p-value $< \alpha = 0.05$. The hypothesis for this study is as follows:

Table 6. Hypothesis 2

H_0	:	The context-based PISA principle learning method is not effective in improving students' computational thinking ability.
H_1	:	The context-based PISA principle learning method is effective in improving students' computational thinking ability.

Table 7. Hypothesis 3

H_0	:	The context-based PISA principle learning method is not effective in improving students' mathematical reasoning ability.
H_1	:	The context-based PISA principle learning method is effective in improving students' mathematical reasoning ability.

RESULT AND DISCUSSION

Result

Descriptive Statistics

Statistical data on the computational thinking abilities of students in both the control and experimental groups are presented in [Table 8](#).

Table 8. Statistical Data of Students' Computational Thinking

Statistical Data	Class	
	Control	Experiment
Number of Students	32	32
Average	77.17	84.37
Median	80.43	84.78
Standard Deviation	16.15	11.20
Range	52.18	47.83
Highest Score	100	100
Lowest Score	47.82	52.17
Minimum Possible Score	0	0
Maximum Possible Score	100	100

Based on [Table 8](#), it can be observed that the average computational thinking ability of students in the experimental class (84.37) is higher than that of the control class (77.17). Additionally, the standard deviation in the experimental class (11.20) is smaller than in the control class (16.15), indicating that the variation in student scores is lower in the experimental class. Next, statistical data on students' mathematical reasoning abilities are presented in [Table 9](#).

Table 9. Statistical Data of Students' Mathematical Reasoning

Statistical Data	Class	
	Control	Experiment
Number of Students	32	32
Average	74.84	85
Median	75	85

Statistical Data	Class	
	Control	Experiment
Standard Deviation	13.4	10.21
Range	70	40
Highest Score	95	100
Lowest Score	35	60
Minimum Possible Score	0	0
Maximum Possible Score	100	100

In Table 9, the average mathematical reasoning ability of students in the experimental class (85.00) is higher than that of the control class (74.84). Furthermore, the standard deviation of the experimental class (10.21) is smaller than that of the control class (13.40), suggesting that the distribution of data in the experimental class is more homogeneous. The range of values for the experimental class is also smaller (40) compared to the control class (70), indicating that the learning outcomes in the experimental class are more consistent.

Prerequisite Test

A multivariate normality test was conducted using the Mardia test, assisted by R Studio, with the results presented in Figure 1.

SmultivariateNormality				
	Test	Statistic	p value	Result
1	Mardia Skewness	7.63524311057435	0.105891403821314	YES
2	Mardia Kurtosis	0.0123819386310459	0.990120894765687	YES
3	MVN	<NA>	<NA>	YES

Figure 1. Mardia Normality Test Output

Based on Figure 1, the results of the skewness test yielded a p-value of 0.105 ($> \alpha = 0.05$), and the kurtosis test showed a p-value of 0.99 ($> \alpha = 0.05$). These results indicate that the research data is multivariate normal.

The homogeneity test of the covariance matrix between groups was conducted using Box's M test, assisted by R Studio, with the results shown in Figure 2.

Box's M-test for Homogeneity of Covariance Matrices	
data:	irisdata[, 2:3]
Chi-Sq (approx.)	= 1.5402, df = 3, p-value = 0.673

Figure 2. Box M Homogeneity Test Output

Based on Figure 2, the p-value obtained is 0.673 ($> \alpha = 0.05$), which leads to the conclusion that there is homogeneity of the covariance matrix between groups in the research data.

Hypothesis Test

1. Hypothesis Test 1: The Effect of Learning Methods

To test the effect of learning methods on computational thinking and mathematical reasoning abilities simultaneously, Hotelling's T^2 test was conducted using R Studio. The results of the test are presented in Figure 3.

Hotelling's two sample T2-test	
data:	gabung by zz
T.2	= 4.9007, df1 = 2, df2 = 49, p-value = 0.01148
alternative hypothesis:	true location difference is not equal to c(0,0)

Figure 3. Hotelling T^2 Test Output

Based on Figure 3, the p-value is 0.01 ($< \alpha = 0.05$), which means that H_0 is rejected. Therefore, it can be concluded that there is an effect of learning methods on students' mathematical reasoning and computational thinking abilities.

2. Hypothesis Test 2: The Effectiveness of Learning Methods on Computational Thinking

Next, a t-test was conducted to compare computational thinking abilities between the control class and the experimental class. The results of the test are presented in Figure 4.

```
Two Sample t-test
data: Data_Uji_T_CT$`Computational Thinking` by Data_Uji_T_CT$Perlakuan
t = 1.1562, df = 56, p-value = 0.2525
alternative hypothesis: true difference in means between group 1 and group 2 is not
equal to 0
95 percent confidence interval:
-2.408936  8.985217
sample estimates:
mean in group 1 mean in group 2
85.41374      82.12560
```

Figure 4. T-Test Results for Computational Thinking Ability

Based on Figure 4, the p-value is 0.2525 ($> \alpha = 0.05$), indicating that H_0 is accepted. Therefore, it can be concluded that the context-based PISA principle learning method is not significantly effective in improving students' computational thinking abilities.

3. Hypothesis Test 3: The Effectiveness of Learning Methods on Mathematical Reasoning

The t-test was also conducted for mathematical reasoning ability, with the results shown in Figure 5.

```
Two Sample t-test
data: Data_Uji_T_PM$`Penalaran Matematis` by Data_Uji_T_PM$Perlakuan
t = 2.5084, df = 56, p-value = 0.01505
alternative hypothesis: true difference in means between group 1 and group 2 is not
equal to 0
95 percent confidence interval:
1.376229 12.291632
sample estimates:
mean in group 1 mean in group 2
83.87097      77.03704
```

Figure 5. T-Test Results for Mathematical Reasoning Ability

Based on Figure 5, the p-value is 0.01 ($< \alpha = 0.05$), indicating that H_0 is rejected. Thus, it can be concluded that the context-based PISA principle learning method is effective in improving students' mathematical reasoning abilities.

Discussion

The results of this study reveal several important findings regarding the application of context-based PISA principles in mathematics learning and their impact on students' computational thinking and mathematical reasoning abilities. The following discussion provides an in-depth analysis of these findings, focusing on the three main aspects that constitute the core of this study

The Effect of Learning Methods on Students' Computational Thinking and Mathematical Reasoning Abilities

The results of the multivariate analysis using Hotelling's T^2 test revealed a significant effect of the context-based PISA principles on students' mathematical reasoning and computational thinking abilities simultaneously ($p = 0.02 < 0.05$). This finding supports the hypothesis that a contextual learning approach aligned with PISA principles can effectively enhance both abilities as an integrated unit of mathematical competence.

These results are consistent with the findings of [Csapó & Molnár \(2019\)](#), who emphasized that contextual learning can stimulate higher-order thinking skills simultaneously. The concurrent development of both abilities suggests a cognitive connection between mathematical reasoning and computational thinking, as stated by [Lockwood et al., \(2022\)](#), who argued that both share a common epistemological foundation rooted in logical and systematic thinking.

Further support comes from recent research by [Benton et al., \(2016\)](#), which demonstrated that contextual, problem-based learning environments foster the development of complex cognitive processes, including mathematical reasoning and computational thinking. Their findings indicate that when students engage with relevant contextual problems, multiple cognitive pathways are activated in parallel, reinforcing both capabilities.

[Gravemeijer et al., \(2017\)](#), in a longitudinal study, highlighted that contextual learning emphasizing real-world relevance as embraced by PISA facilitates the development of integrated mathematical competencies. This aligns with [Wing \(2006\)](#) assertion that computational thinking is inherently linked to mathematical reasoning, particularly in addressing complex problems.

Comparative study of educational practices across European countries, identified a positive correlation between the adoption of PISA principles and improvements in students' multidimensional cognitive skills. Their findings underscore that focusing on contextual problems can simultaneously activate diverse cognitive domains, including reasoning and computational thinking.

This simultaneous enhancement is further validated by [Schoenfeld \(2016\)](#) research, which emphasized that authentic and contextual learning experiences provide optimal conditions for cultivating integrated mathematical skills required in the 21st century. The interrelationship between mathematical reasoning and computational thinking is strengthened through instructional approaches that prioritize solving real-world problems, as advocated in the PISA framework.

Effectiveness of Learning with Contextual-Based PISA Method Reviewed from Computational Thinking Ability

In contrast to computational thinking, the results of the univariate analysis showed that the application of contextual-based PISA principles was effective in significantly improving students' mathematical reasoning abilities ($p = 0.01 < 0.05$). This finding indicates that a learning approach that adopts PISA principles with an emphasis on meaningful and relevant contexts has a strong positive impact on the development of mathematical reasoning abilities.

These results are consistent with the research of [Mercier & Sperber \(2017\)](#), who emphasized that mathematical reasoning develops optimally when students are engaged in a meaningful learning context that is relevant to real-world experiences. They found that contextual learning provides a conducive environment for developing students' abilities to draw logical conclusions and construct valid mathematical arguments.

These findings also support the arguments put forward by [Brodie et al., \(2010\)](#) and [Mata-Pereira & da Ponte \(2017\)](#), who noted that mathematical reasoning grows through the process of asking and answering critical questions about mathematical truths in a meaningful context. The context-based PISA principles appear to effectively create a learning environment that encourages students to engage with these questions, thereby strengthening their reasoning skills.

[Reid & Knipping \(2021\)](#), in their recent study, found that a learning approach emphasizing the application of mathematics in real-world contexts such as the one proposed by the PISA principles significantly improves students' ability to construct and justify mathematical arguments. This result aligns with the mathematical reasoning indicators proposed by [Sumarmo \(2018\)](#) and [Stylianides \(2016\)](#), highlighting the importance of authentic mathematical practice in promoting deeper reasoning abilities.

A comparative study by [Thompson et al., \(2017\)](#) across various OECD countries also showed that a learning approach aligned with the PISA principles consistently resulted in improvements in students' quantitative reasoning abilities, particularly in non-routine situations. Their research identified that contextualizing mathematical problems helped students transfer their

knowledge and reasoning skills to new, unfamiliar contexts, demonstrating the transferability of learning through contextualized teaching.

Herbert et al., (2019) in their longitudinal study found that sustained exposure to contextual mathematical problems led to significant improvements in students' logical argumentation and mathematical justification abilities. They emphasize that authentic learning experiences such as those promoted by the PISA principles play a crucial role in developing robust mathematical reasoning skills.

Recent research by Lithner (2017) further reinforces these findings, showing that contextual problem-based learning aligned with PISA principles fosters optimal conditions for the development of mathematical creative reasoning. This component of reasoning is critical to overall mathematical thinking, as it allows students to employ flexible and adaptive strategies to solve complex problems.

Zulnaidi et al., (2020) in their international study, identified that learning that emphasizes authentic contexts successfully helped students overcome difficulties in developing both deductive and inductive reasoning in mathematics. They emphasized that context-based PISA principles assist students in making connections between abstract mathematical concepts and real-world applications, which is a key factor in developing effective mathematical reasoning.

Effectiveness of Contextual-Based PISA Learning in Terms of Mathematical Reasoning Ability

The results of the univariate analysis using the t-test indicated that the application of contextual-based PISA principles was less effective in enhancing students' computational thinking abilities ($p = 0.25 > 0.05$). Although there was an increase in the average score in the experimental group, the improvement did not reach statistically significant levels. This finding raises important questions regarding the factors that influence the development of computational thinking within the context of mathematics learning.

These results align with the research of Kalelioglu et al., (2019), who found that the development of computational thinking requires a more specific and structured pedagogical approach than the general contextual approach. Their study highlighted that computational thinking necessitates explicit scaffolding and repeated practice, elements that may not have been optimally incorporated into the implementation of the context-based PISA principles in this study.

Weintrop et al., (2016) also emphasized that computational thinking has unique characteristics that require a more technical and algorithmic approach. They suggest that the development of computational thinking should combine contextual learning with structured practice, focusing on specific components such as decomposition, pattern recognition, abstraction, and algorithms, as identified by Supiarmo et al., (2021) in their research.

Computational thinking takes longer to develop compared to conventional mathematical skills. They proposed that pedagogical interventions aimed at improving computational thinking should ideally be carried out over a longer period with higher intensity. This longer timeline could be a limitation of the current study's design.

The findings also reflect those reported by Azizah et al., (2022), who noted that students' computational thinking abilities remain relatively low, especially in areas such as pattern recognition, information analysis, abstraction, and algorithms. This indicates that the challenges in fostering computational thinking are multifaceted and demand a more comprehensive and sustainable pedagogical approach.

Additionally, Sentence & Csizmadia (2017), in their longitudinal study across several European countries, identified that effective development of computational thinking requires a pedagogical approach that extends beyond contextual learning alone. They emphasize the importance of integrating explicit instruction with contextual problem-based learning to achieve optimal results.

Roman-Gonzalez et al., (2018) also Socio-economic factors and access to technology play a significant role in the development of computational thinking. These factors, which may have acted as uncontrolled intervening variables in this study, highlight the need to account for such contextual influences when designing future pedagogical interventions aimed at improving computational thinking.

CONCLUSION

Based on the results of the research and analysis that have been conducted, it is concluded that there is an influence between the contextual PISA principle-based learning method and conventional learning on students' mathematical reasoning and computational thinking abilities. The PISA principle-based learning method has proven effective in improving students' mathematical reasoning abilities, but has not shown optimal effectiveness in improving computational thinking abilities..

Teachers can use the contextual PISA principle-based learning approach as an alternative in developing students' mathematical reasoning abilities. This approach has the potential to be applied to the development of various other competencies in different mathematical materials, which makes it a valuable reference for further research.

This study has several limitations that need to be considered. The implementation carried out in a limited time may not be enough to develop computational thinking skills in depth. The scope of the study only covers one school with certain characteristics, so the results cannot be generalized widely. In addition, the limited scope of material and instruments that are still in the development stage can affect the accuracy of the measurement. External factors such as family support and access to technology outside of learning are also not fully controllable, which may have had an impact on the outcomes.

For future research, it is recommended to explore the impact of the contextual PISA principle-based learning approach over a longer period, as this may lead to a deeper development of computational thinking skills. Additionally, broadening the scope of the study to include more schools with diverse student populations could provide a more comprehensive understanding of the method's effectiveness. Integrating more specific and structured exercises focusing on computational thinking, as well as addressing the external factors affecting student learning, could further optimize the effectiveness of this learning approach.

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Developing an optimal design of the *Sekolah Perempuan* website to empower women's financial independence

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ABSTRACT

Women are often associated with a lack of economic independence, which hinders their ability to make autonomous financial decisions. The development of the *Sekolah Perempuan* website aims to address the significant challenge of women's financial independence, exacerbated by limited access to education and persistent social stigma. This study focuses on creating an optimal design framework that empowers women through the effective use of digital resources. By employing a mixed-methods approach, including both quantitative and qualitative methods, the research utilizes the ADDIE model to guide the website's development. A sample of 35 women participants was surveyed to assess their financial independence before and after engaging with the *Sekolah Perempuan* website. The data collection instruments included structured surveys, which revealed a significant improvement in financial autonomy, indicated by a mean difference ($p < 0.001$). The design framework consists of three key components: (1) Promoting Women Empowerment through educational initiatives that enhance self-confidence, financial literacy, and digital skills; (2) Enhancing Digital Marketing Skills by developing competencies in digital knowledge and marketing strategies; and (3) Supporting Financial Independence through integrated marketing tools and educational resources. The findings demonstrate a positive impact, with participants reporting new income sources and increased financial confidence. This study underscores the potential of digital platforms to foster women's financial independence and offers sustainable solutions for long-term empowerment. Future research should explore the application of this framework across various digital platforms to further enhance women's empowerment initiatives.



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INTRODUCTION

Women's empowerment has emerged as a pivotal focus in global socioeconomic development, significantly impacting poverty reduction, social justice, and economic growth. The United Nations' Sustainable Development Goals (SDGs), particularly Goal 5, underscore the

necessity of achieving gender equality and empowering women and girls, which is essential for broader development objectives (Mishra, 2014; Shetty & Han, 2015). Empirical evidence shows that economies that prioritize gender equity tend to outperform those with entrenched disparities, maximizing social output and fostering sustainable growth (Diachkova & Kontoboitseva, 2022). In particular, educational empowerment equips women with the knowledge and confidence to engage effectively in political, social, and economic spheres, enhancing their decision-making capabilities and practical skills for economic activity (Shetty & Han, 2015). Studies indicate that increased gender equality leads to improved economic performance and reduced income inequality, crucial for achieving overarching economic goals (Samuda, 2023). Furthermore, gender equality encompasses social, economic, and political dimensions, dismantling biases that hinder women's contributions (Ngulube et al., 2024). As highlighted by Rohmatilah (2023), empowering women is integral to poverty alleviation, reinforcing the multifaceted benefits of women's empowerment. Without addressing gender disparities, the pursuit of sustainable development remains compromised (Jayashree, 2023; Khanal, 2023). Thus, robust interventions to enhance women's roles in decision-making and economic participation are essential for fostering inclusive growth.

The goal of women's empowerment is to enhance economic activity, particularly addressing the challenges women face in achieving financial independence due to societal stigma. Due to a confluence of cultural, economic, and policy-related issues, women continue to encounter a number of obstacles in their quest for financial independence. Women's engagement in the workforce is frequently restricted by social conventions, which mostly assign them to caring and domestic duties. This relationship perpetuates financial reliance on male family members or partners, especially in situations where market institutions and policies uphold the traditional male breadwinner model (Hirani et al., 2025; Pandey, 2024; Huber et al., 2009). Equal access to jobs, training, and education, as well as wage equity, is also essential for financial independence. However, women frequently face large pay disparities and few employment options, especially in fields like retail and caregiving, where a large proportion of the workforce is female and where pay and benefits are generally lower than in male-dominated industries (Sanze et al., 2024; Alper, 2019).

Reducing gender gaps and promoting sustainable economic growth are largely dependent on empowering women's programs. The program aims to increase women's awareness and capability to become financially independent. The ability of women to earn, manage, and control their resources is known as financial independence. It allows them to make independent decisions and lessens their vulnerability in social and familial institutions (Frecheville-Faucon, 2023). Such empowerment greatly enhances social and economic stability at the national level, in addition to being beneficial to individuals. Societies can gain from a variety of contributions to productivity and innovation by bolstering women's financial standing, especially when they enter and have an impact on fields like community development and entrepreneurship (Dhamayanti et al., 2022; Thomas, 2024; Huber et al., 2009).

Programs for economic empowerment in developing countries frequently concentrate on entrepreneurship, financial resource access, and skill development. These government and non-governmental organization-led initiatives have been successful in helping women launch and grow small enterprises, enhancing the economic resilience of households and communities. Research indicates that women become effective change agents when they achieve financial independence, using their earnings to support family welfare, such as nutrition, healthcare, and education (Sanze et al., 2024; Nurhayati et al., 2023; Moghadam & Senfova, 2005). Additionally, women who are financially independent are more inclined to support policies that benefit their communities and fight for their rights, which has been connected to increased civic and political participation (Shoukat et al., 2023).

Recently, one crucial step in closing the digital divide and promoting financial independence has been the incorporation of technology and digital tools into empowerment initiatives. The development of an optimized website, such as *Sekolah Perempuan*, plays a pivotal role in this context by serving as a centralized platform for learning, networking, and entrepreneurial development. A user-centered design approach is essential to ensure accessibility, inclusivity, and relevance to the needs of diverse groups of women, particularly those in rural or marginalized

communities (Pea, 1987; Norman & Draper, 1986). Features such as multilingual content, mobile responsiveness, interactive learning modules, and integrated e-commerce capabilities can significantly enhance engagement and usability (Han, 2020). Moreover, the platform can support blended learning models that combine online education with offline mentorship, fostering community-driven growth and peer-to-peer support (World Economic Forum, 2021). By focusing on digital literacy, financial education, and entrepreneurial skill-building, *Sekolah Perempuan* can empower women to make informed economic decisions, access broader markets, and build sustainable income streams (UNCTAD, 2022; OECD, 2022). This digital initiative not only addresses structural barriers but also aligns with national and global gender equity strategies, positioning technology as a transformative enabler of women's empowerment.

This research addresses a critical gap in the intersection of technology and women's empowerment. Unlike previous studies that predominantly focused on traditional educational methods, this research emphasizes the integration of digital platforms tailored specifically for women, particularly in underserved communities. For instance, several previous authors have only focused on enhancing important skills related to finance and economics through workshops and other conventional methods (Daniels et al, 2022; Khan et al., 2022). Current trends in research highlight the importance of digital resources in enhancing women's economic participation, yet few have explored the optimal design elements that facilitate user engagement and accessibility. This aligns with Tawab (2024) insights, which underscore that a consideration of design elements is crucial for ensuring that digital environments are both safe and conducive to women's active participation in digital economic activity. By leveraging technology to address financial independence, this research aligns with global initiatives advocating for gender equality, while also contributing innovative insights into the effective use of digital tools in empowerment strategies. This dual focus on design and empowerment represents a novel approach in the ongoing discourse surrounding women's financial autonomy.

In sum, achieving women's empowerment requires a multifaceted approach that combines educational initiatives, financial empowerment strategies, and technology-driven solutions. This study focuses on several targets, which include: (1) fostering optimal website design for the Women Empowerment program; (2) developing a blueprint Entrepreneurship Website in supporting entrepreneurship education for women; and (3) the effectiveness of *Sekolah Perempuan* Website in enhancing Financial Independence. By addressing these objectives, the study aims to provide a comprehensive framework that not only supports women in establishing financial independence but also creates sustainable pathways for long-term empowerment in the digital economy. This research contributes to the field by providing a user-centered design framework for digital platforms, enhancing women's financial independence through accessible online resources, and fostering community engagement in underserved populations.

METHOD

This study is a research and development study that employs a qualitative and quantitative approach to examine the impact of *Sekolah Perempuan* Website in empowering women's financial independence. The research methodology is designed to capture both quantitative and qualitative data. The approach includes three primary stages: (1) designing the framework model for *Sekolah Perempuan* Website to empower women's financial independence; (2) developing the Entrepreneurship Website; and (3) data collection through surveys and interviews with participants of *Sekolah Perempuan*. This data aims to assess the effectiveness of the Website in enhancing women's financial independence. This multi-layered methodology allows for a robust understanding of how digital marketing technologies influence financial empowerment and offers insights into optimizing these tools to support broader economic inclusion for women.

To develop an effective entrepreneurship website for *Sekolah Perempuan*, this study applies the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. This model provides a structured approach to guide the website's development, ensuring it aligns with the specific needs of women entrepreneurs to enhance their marketing capabilities. The stages of

development include: (1) Analysis Stages: This initial phase involves understanding the needs of *Sekolah Perempuan*'s participants. The findings from this analysis help tailor the website to support women entrepreneurs effectively; (2) Design stages: Based on the analysis phase, design the framework model for *Sekolah Perempuan* Website for Women Empowerment program. This phase focuses on creating a clear conceptual framework for how to design the *Sekolah Perempuan* website model for the Women Empowerment program. (3) Development stages: In this development phase, the website functionalities are built. This phase also includes database integration to manage user data securely and ethically, and backend development to ensure the platform's scalability and reliability. (4) Implementation and Evaluation Stages: The website is launched for the participants of *Sekolah Perempuan*. During this phase, training sessions are conducted to familiarize users with the platform's features. Moreover, this final phase assesses the website's effectiveness in supporting women's financial independence.

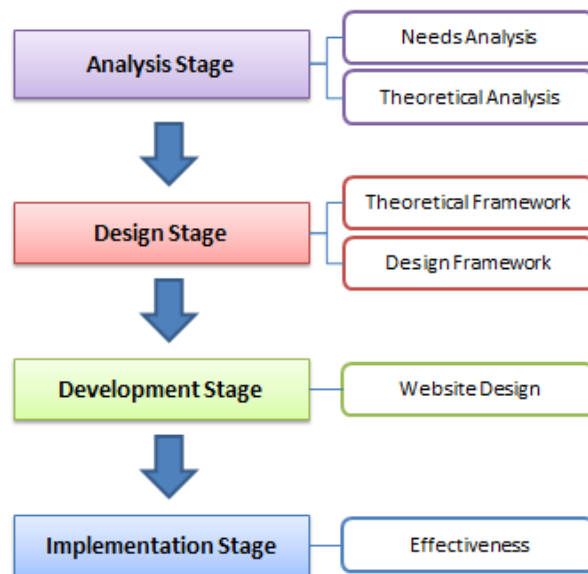


Figure 1. Research Scheme

The research involves a sample of 35 women participants from the *Sekolah Perempuan* program. This group consists of both married and unmarried women, ensuring diverse representation in the study. The selection criteria for participants were based on their engagement with the *Sekolah Perempuan*'s empowerment programs. The data collection instruments include structured surveys that assess participants' financial independence before and after engaging with the *Sekolah Perempuan* website. Quantitative data are analyzed using statistical methods, including one-sample t-tests, to determine the significance of changes in financial independence among participants. The statistical results indicate a significant mean difference ($p < 0.001$), confirming the effectiveness of the *Sekolah Perempuan* program in enhancing women's financial autonomy.

Table 1. Indicator and Item of Survey

No.	Indicator	Definition	Item
1	Website Usability	The usability section evaluates participants' experiences with the <i>Sekolah Perempuan</i> website. It includes questions regarding the ease of navigation, visual appeal, helpfulness of resources, and frequency of technical issues encountered.	1. How would you rate the ease of navigating <i>Sekolah Perempuan</i> 's website? 2. How visually appealing is the website design? 3. How helpful are the website's resources (articles, videos, courses) in understanding the content? 4. How often do you experience technical issues while using the website?
2	Content Validity	This section assesses the relevance, clarity, and overall	5. How relevant is the content on <i>Sekolah Perempuan</i> to your needs for financial and

No.	Indicator	Definition	Item
3	Skill Development	quality of the educational content provided on the website. Participants rate how well the content meets their needs for financial and personal empowerment, as well as their satisfaction with the resources available.	personal empowerment?
			6. How clear and easy to understand is the educational content provided?
			7. Do you feel that the website provides adequate practical knowledge for managing finances?
4	Impact on Financial Independence	Participants reflect on their confidence in managing personal finances and the acquisition of new financial management skills through the website. This section aims to capture changes in participants' abilities and confidence levels after engaging with the website's resources.	8. How satisfied are you with the overall quality of educational resources provided on the website?
			9. After using the resources on <i>Sekolah Perempuan</i> , do you feel more confident in managing your personal finances?
			10. I have learned new skills related to financial management (e.g., budgeting, saving, investing) through the website.
4	Impact on Financial Independence	The final section focuses on the perceived impact of the <i>Sekolah Perempuan</i> website on participants' financial independence. Questions address changes in financial status, the ability to earn additional income, and feelings of empowerment in making financial decisions.	11. The skills I have learned from <i>Sekolah Perempuan</i> support my daily work activities.
			12. How has <i>Sekolah Perempuan</i> impacted your financial independence?
			13. Since using the website, have you started earning additional income through any of the skills or knowledge gained?
4	Impact on Financial Independence		14. To what extent do you feel empowered to make financial decisions independently after engaging with <i>Sekolah Perempuan</i> ?

RESULTS AND DISCUSSION

Results

Analysis and Design Stage

The analysis and design stages include analyzing theoretical stances which included in the design framework. The design framework of *Sekolah Perempuan* is based on theoretical analysis. According to the analysis process, the result shows three main parts in the design of the design framework (Figure 1) of *Sekolah Perempuan* Website to empower Women Financial Independencies, including: (1) Promoting Women Empowerment; (2) Enhance digital marketing skills; (3) Support Financial Independencies (Figure 2). The design framework illustrated in the image serves as a comprehensive roadmap for promoting women's empowerment through educational initiatives and digital marketing strategies. At the core of this framework is the emphasis on enhancing women's educational empowerment, which is crucial for building self-confidence and financial literacy. By integrating digital skills training, the framework addresses the need for women to acquire essential competencies in digital literacy, digital security, and digital knowledge. This educational foundation is supported by various studies, highlighting the importance of equipping women with the skills necessary to navigate the digital landscape effectively. The framework also emphasizes the development of marketing skills, essential for women to engage successfully in the digital marketplace, thereby fostering their economic independence.

Additionally, the framework outlines a structured approach to creating a digital market platform that supports women's financial independence. This involves establishing an empowerment center that focuses on guiding women through the complexities of digital marketing and entrepreneurship. The skills development center plays a pivotal role in providing targeted

training in areas such as market planning and marketing communication. Furthermore, the marketing tools center is designed to enhance user experience through effective user interface design and content marketing strategies. By integrating these elements, the framework not only supports women's empowerment but also facilitates their active participation in the digital economy, ultimately contributing to their financial independence and overall well-being. This holistic approach underscores the significance of combining education, digital skills, and marketing expertise to create sustainable pathways for women's empowerment.

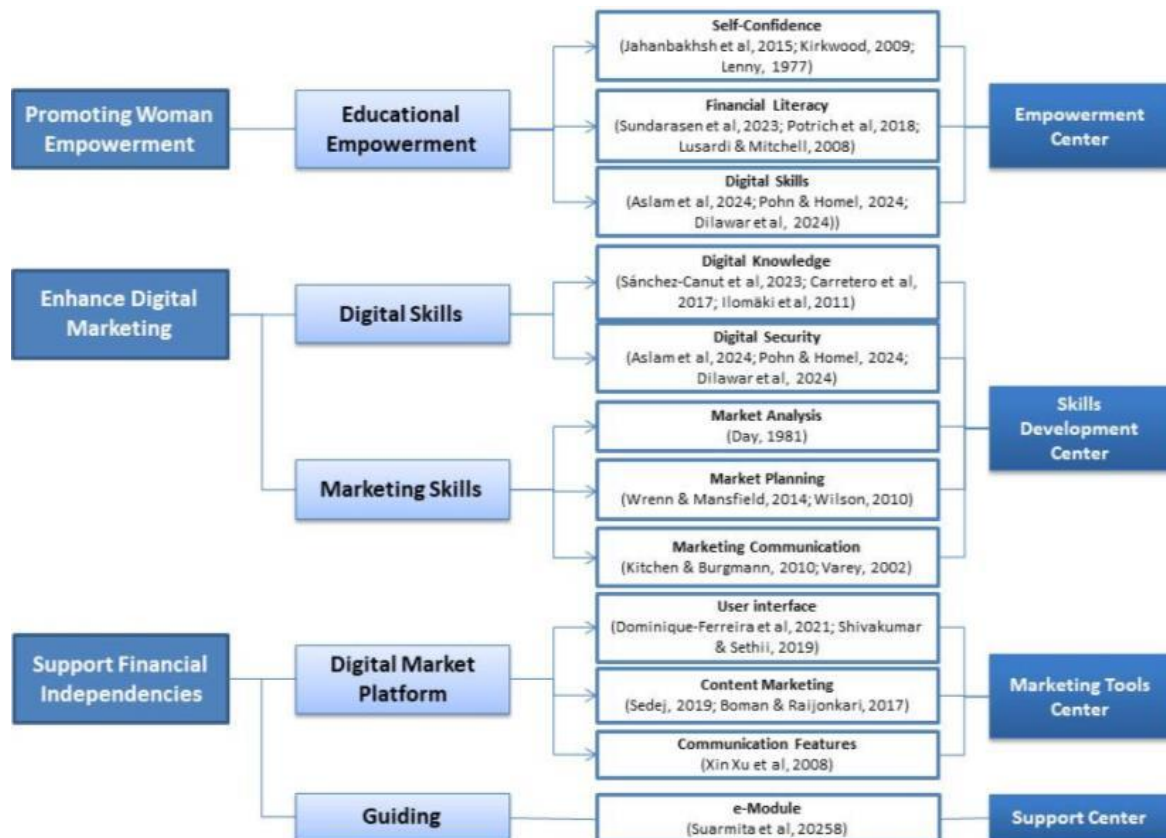


Figure 2. Design Framework of Sekolah Perempuan Website to Empower Women's Financial Independence

Developing Stage

The development of *Sekolah Perempuan's* entrepreneurship website aims to create a dynamic digital platform that gives women entrepreneurs the tools they need to manage and expand their firms. The implementation of the Website could also be beneficial in providing empowerment programs for women, such as educational entrepreneurship programs, workshops, and training. Moreover, the website is becoming a medium to improve women's capacity in conducting creative business by providing market marketplace which possible to advance the local market, promote better customer connection, increase market positioning, and embrace modern technology to promote their handmade local product. The *Sekolah Perempuan* website features vocational items made by students and is intended to serve as a comprehensive information and marketing platform. This website also functions as a digital learning center, providing a range of educational resources on vocational skills and entrepreneurship. The Websites of *Sekolah Perempuan* can be accessed through this link: <https://sekolahperempuan.com/> (Figure 3).

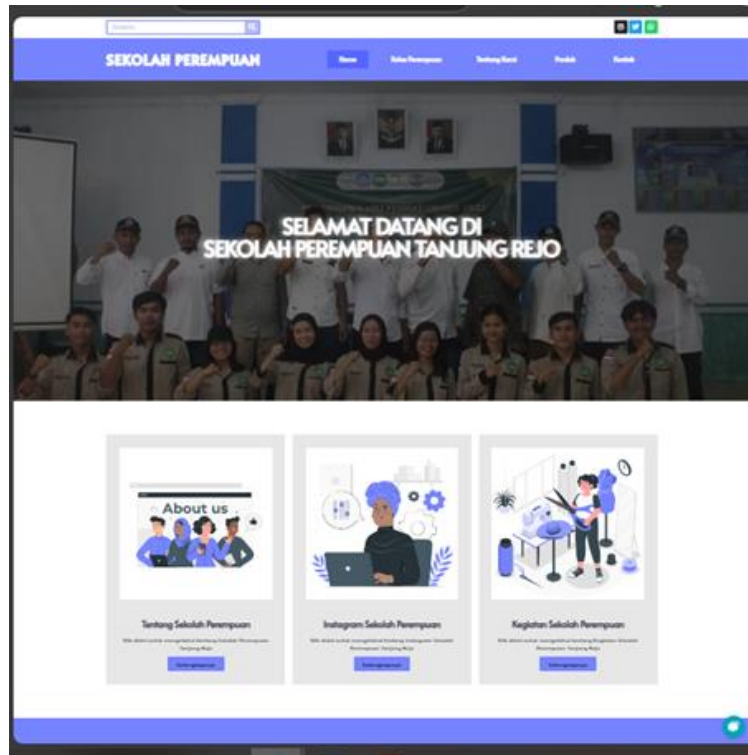


Figure 3. The Home Display of *Sekolah Perempuan*'s Website

There are several components designed to support user engagement and content personalization. On the *Sekolah Perempuan* website, features such as product and service recommendations aim to promote participants' products and services, including available courses. For example, if a user frequently visits training pages, the website can be designed to adjust the homepage content to reflect the user's interests. This helps increase engagement and encourages users to register for relevant programs. Additionally, *Sekolah Perempuan* includes promotional features to showcase vocational products through digital marketing strategies. The development process begins with a promotional script, followed by the creation of a marketing video for *Sekolah Perempuan* (Figure 4).

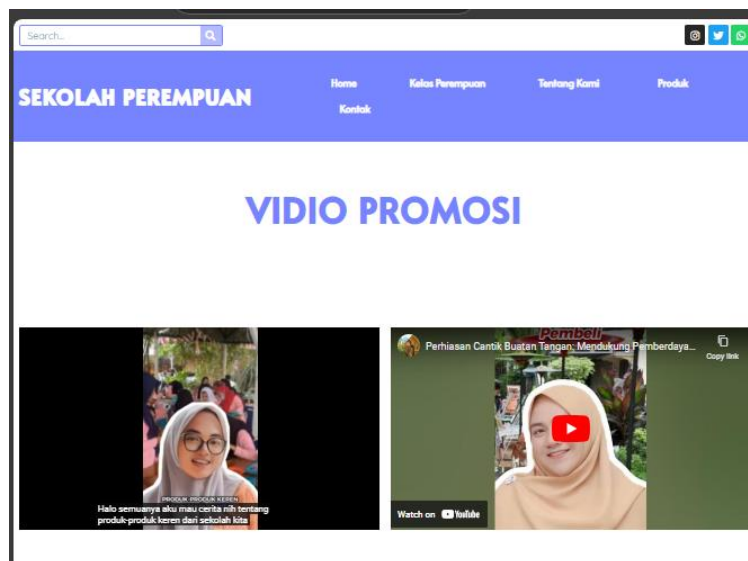


Figure 4. The Display of Marketing Video

In addition to promotional videos, the *Sekolah Perempuan* website includes features designed to enhance user interaction and support. One such feature is the use of interactive messaging tools or chatting platforms that provide responses to user inquiries in real time. These tools follow predefined scripts and decision trees to guide conversations and assist users effectively (Figure 5). By maintaining regular communication and offering consistent support through the website's messaging system, *Sekolah Perempuan* enhances user experience and engagement. These tools help address user questions and needs promptly, which contributes to improving the overall effectiveness of the website's digital marketing and communication strategies.

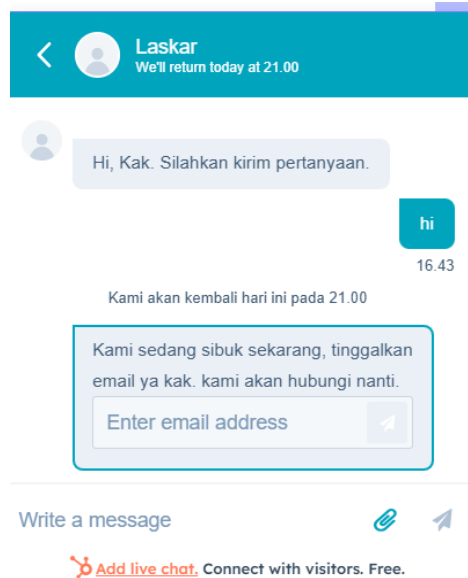


Figure 5. The Display of Messaging Tools or Chatting Platform

Sekolah Perempuan also incorporates a women's educational empowerment program through its "*Kelas Perempuan*" initiative (Figure 6). This program covers a range of topics, including business seminars, health programs (such as stunting prevention), and computer literacy courses. Each class is led by professional tutors with extensive experience in their respective fields. Additionally, the program provides learning modules and books to participants as reading materials and practical guides, enriching the overall educational experience. It is important to note that each program under *Kelas Perempuan* not only focuses on developing knowledge but also equips women with practical skills to support entrepreneurship.



Figure 6. The Educational Empowerment Programs for Women provided by *Sekolah Perempuan*

Implementation Stage

The implementation stage includes an effectiveness test to provide evidence that the developed website can have an impact on women's financial independence. The results of the one-sample t-test suggest that the effectiveness of Women's Empowerment by using *Sekolah Perempuan's* Websites in enhancing Financial Independence is statistically significant. With a mean difference of 57.14 and a confidence interval of 95%, the range of difference falls between 54.04 and 60.25. The t-value is 37.371, and the p-value (Sig. 2-tailed) is 0.000, indicating a highly significant result. This result suggests that women's financial independence has been significantly enhanced by the empowerment initiative, which uses digital marketing via a *Sekolah Perempuan's* website. The substantial mean difference indicates that the participants benefited significantly from financial empowerment, demonstrating the efficacy of the digital platform in encouraging women to become financially independent. Such a finding bolsters the case for using cutting-edge digital tools in empowerment initiatives to help women achieve financial independence and prosperity.

Table 2. Statistics Result on the Effectiveness of the Women's Empowerment Program

	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Effectiveness	37.371	34	.000	57.14286	54.0354	60.2503

Discussion

Elements of Design Framework on *Sekolah Perempuan* Website to Empower Women's Financial Independence

The design framework for empowering women through digital marketing aims to provide a structured approach to enhancing women's financial independence. This framework integrates advanced digital marketing techniques with empowerment strategies tailored to the unique challenges faced by women entrepreneurs, such as limited access to capital, market networks, and training opportunities (UN Women, 2020; IBCSD, 2024). By employing tools like customer segmentation, personalized marketing, and data-driven campaign strategies, the framework seeks to optimize outreach, engagement, and conversion for women-led businesses. It emphasizes practical, technology-based skill development and improved digital literacy, equipping women with the tools necessary to grow and sustain their enterprises in competitive marketplaces (World Bank, 2019).

The first element of the design is promoting women's empowerment, which emphasizes the implementation of educational empowerment as a transformative tool. The main idea is that education is not only a medium for knowledge acquisition, but also a strategic approach for enabling women to develop the skills, confidence, and financial competence required for greater autonomy and socio-economic participation. This process leads to the formation of an Empowerment Center, which is a space, physical or symbolic, where women are supported to thrive. The first critical component derived from educational empowerment is self-confidence. As emphasized by Jahanbakhsh et al., (2015), Kirkwood (2009), and Lenney (1977), self-confidence is the foundation for empowering women to believe in their capabilities, voice their opinions, and take initiative in both personal and professional spheres. Educational settings foster self-efficacy by providing knowledge, exposure, and opportunities for participation, which in turn cultivates a sense of agency. Women with higher self-confidence tend to pursue leadership roles, challenge societal limitations, and make decisions that might have massively affected their future. The second component is financial literacy, which is essential for enabling women to achieve financial independence and stability. According to Sundarasan et al., (2023), Potrich et al., (2018), and Lusardi & Mitchell (2008), financial literacy encompasses the understanding of financial principles such as budgeting, saving, financial management, and financial planning. The importance of financial skills for women could be beneficial for their ability to make correct decisions, avoid financial risks, and build sustainable livelihoods. This knowledge empowers women to start or expand businesses, manage household finances, and contribute to their communities economically. The third component is digital skills, which reflects the necessity of digital literacy in modern

society. As mentioned by [Aslam et al., \(2024\)](#), [Pöhn & Homel \(2024\)](#), and [Dilawar et al., \(2024\)](#), digital skills go beyond basic computer and technological use. The digital skills are more likely to include the ability to access and evaluate online information, use communication technologies, engage with digital platforms for learning or business, and ensure cybersecurity. In today's technology-driven economy, digital literacy enables women to participate in e-learning, remote work, e-commerce, and online networking. These skills give an opportunity towards new economic and educational opportunities, particularly for underprivileged women or women who live in remote areas. The combination of these three components could provide a fundamental basis to create an educational empowerment program that leads to the development of the output that is the Empowerment Center to support women's holistic growth. This output may manifest in the form of community hubs or online platforms where women receive continued access to education, mentoring, resources, and a supportive environment for personal and professional development.

The second element of the design framework is enhancing digital marketing through the development of two core competencies: digital skills and marketing skills. As digital transformation continues to shape modern economies, women and marginalized groups require strong digital literacy and marketing capabilities to stay competitive and expand their economic participation. The first competency is Digital skills, which is the cornerstone of success in today's technology-driven world, particularly as more economic and social activities shift into digital spaces. These skills encompass a broad range of abilities, starting with digital knowledge, which refers to the capacity to effectively use digital tools, platforms, and online resources. According to [Sánchez-Canut et al., \(2023\)](#), [Boman & Rajonkari \(2017\)](#), and [Ilomäki et al., \(2011\)](#), digital knowledge is not merely about technical knowledge but also involves cognitive flexibility and digital problem-solving skills that are increasingly essential for personal, educational, and professional adaptation in a rapidly evolving digital environment. The capacity to effectively navigate and use digital technology enables people to participate in the digital economy in meaningful ways, whether it be by managing e-commerce platforms, working remotely, or utilizing digital learning tools. The other element of digital skills is digital security, which refers to the knowledge and practices required to safeguard personal data, protect online identities, and maintain the security of digital transactions. According to [Aslam et al., \(2024\)](#), [Pohn & Homel \(2024\)](#), and [Dilawar et al., \(2024\)](#) argue that those who are unaware of the fundamentals of security are potentially at risk of a cyberattack. Online managers of companies or personal brands are particularly susceptible to fraud, scams, and data breaches. Ensuring digital safety means understanding how to create secure passwords, recognize phishing attempts, use encrypted platforms, and implement privacy settings. Therefore, digital skills must be taught in a holistic manner that not only emphasizes technical usage but also builds resilience and confidence in safe digital engagement. The second competency is Marketing skills, which play an important role in designing and executing successful digital marketing strategies. The elements of these competencies include market analysis, which is the foundation of all effective marketing efforts. As highlighted by [Day \(1981\)](#), market analysis involves studying consumer behavior, identifying target audiences, and recognizing emerging market trends. This element is essential to ensure that marketing strategies are relevant to the needs of the audience, rather than being based on assumptions or outdated information. The second element is market planning, which transforms insights from market analysis into strategic actions. This includes determining how a product or service is positioned, how it is priced, and how it will be delivered to the consumer. [Wrenn & Mansfield \(2014\)](#) and [Wilson \(2010\)](#) emphasize that successful marketing execution depends on careful planning, which aligns organizational goals with market opportunities. The comprehension of competitors, differentiating the product, and planning distribution channels effectively is an important factor that leads to business profitability. Although the two previous elements are fundamental for marketing skills, it is not complete without marketing communication as an element that links the business and customers. This element not only conveys the value of a product or service but also creates meaningful engagement with audiences, which leads to an increase in customer trust and fosters long-term loyalty. [Kitchen & Burgmann \(2010\)](#) and [Varey \(2002\)](#) stress the importance of crafting messages that are clear, persuasive, and aligned with brand identity, especially in digital media where attention spans are short and competition is high.

Effective digital communication may include social media content, email campaigns, influencer partnerships, and interactive advertising. The development of these two important competencies/skills (Digital skills and Marketing skills) leads to the formation of the Skills Development Center, which stresses how the *Sekolah Perempuan* Website could provide a program that could enhance the capacity in digital marketing, especially in developing both digital and marketing skills. To sum up, enhancing digital marketing through targeted skill development not only fosters innovation and entrepreneurship but also contributes to inclusive digital economies.

The last element of the design framework is to support financial independence. This element consists of several integration media, including a Digital marketing platform and a Guiding Manual. A Digital Market Platform integration serves as a critical tool that allows users to promote and sell their products or services online. The platform will effectively and optimally function by integrating several key components that enhance functionality, visibility, and user engagement. The key components include User Interface (UI), Content Marketing, and Communication Features. The first component is the User Interface (UI), which directly influences the ease of navigation and overall user satisfaction. According to [Dominique-Ferreira et al. \(2021\)](#) and [Shivakumar & Sethii \(2019\)](#), a well-designed UI increases accessibility and helps users interact with the platform efficiently. This component is vital for someone new to digital commerce who requires straightforward and seamless experiences to confidently engage with online tools. Another critical component is Content Marketing, which involves the strategic creation and distribution of relevant and engaging content to attract and retain customers. [Sedej \(2019\)](#) and [Boman & Rajonkari \(2017\)](#) highlight that content marketing not only improves visibility on digital platforms but also establishes credibility and brand personality. The users can build stronger relationships with their consumers and position their offerings more effectively in a crowded market through the use of videos, social media posts, and product storytelling as content marketing. Besides the robust platform appearance and marketing content, the presence of communication features is also an important component to foster two-way interaction between sellers and customers. [Xu et al., \(2008\)](#) argue that these features help build trust and responsiveness, creating a more personalized and supportive customer experience. The combination of these three components forms the foundation of an effective digital market platform. Their integration leads to the establishment of a Marketing Tools Center, which acts as a centralized hub where users can access, manage, and optimize their marketing efforts. This structure not only empowers entrepreneurs with the tools needed for digital commerce but also supports long-term sustainability. In addition to technical infrastructure, Guiding plays an equally important role as a medium in supporting users toward achieving financial independence. This guidance can be delivered through structured educational resources, such as e-Modules, which offer self-learning through business, financial literacy, and digital marketing skills. According to [Suarmita et al., \(2025\)](#), such modules empower users by equipping them with the knowledge needed to confidently navigate digital markets and make informed financial decisions. The implementation of this educational support results in the creation of a Support Center, which functions not only as a learning facility but also as a source of continuous mentoring for digital entrepreneurs.

Effectiveness of Sekolah Perempuan Websites to Enhance Women's Financial Independence

According to the survey data, a large number of women have started earning an income after taking part in the empowerment program, which indicates a positive impact of the program. There are 11 women out of 35 the participants reported earning a weekly income, but in different quantities. Both married and unmarried women are included, indicating that the program's advantages are applicable to women in a variety of marital situations. The weekly income ranges between IDR 300.000 and IDR 700.000. In particular, a number of people claimed comparatively greater weekly incomes of IDR 600.000 and IDR 700.000. This distribution shows how successfully the program supports women in generating their own money and helps them become financially independent. This phenomenon is consistent with a study conducted by [Sujan \(2016\)](#) and [Sanze et al., \(2024\)](#) that found that women's empowerment programs greatly increased women's financial independence. Many women now enjoy financial independence, control over

their income, and the capacity to make their own financial decisions because of education and skill development. In addition to the financial benefits, this empowerment increases their sense of self-worth and fosters respect within their families and communities.

Besides assessing the number of women who have started earning an income, the effectiveness of the women empowerment program by using *Sekolah Perempuan*'s Websites to enhance Financials independence. *Sekolah Perempuan* is important as a digital marketing platform, especially for supporting women's economic activities, particularly in rural areas where women have traditionally faced barriers to entrepreneurship. [Yuliatiningtyas et al., \(2024\)](#) demonstrate that digital marketing training not only equips women with essential skills but also encourages their participation in economic decision-making within their households and communities, thereby enhancing local economies and promoting gender equity by ensuring women have a voice in economic activities. This is further supported by the findings from a one-sample t-test analysis assessing the effectiveness of the *Sekolah Perempuan* website in enhancing women's financial independence. The results indicate a statistically significant improvement in financial independence, confirming that the digital platform effectively empowers women financially. This aligns with theoretical frameworks emphasizing the role of digital literacy and online resources in promoting women's empowerment and economic participation. The [World Economic Forum \(2020\)](#) highlights that digital platforms can facilitate access to financial services and educational resources, thereby enhancing women's economic agency, reinforcing the importance of integrating technology into empowerment strategies.

In conclusion, the empowerment initiative that makes use of digital marketing via the *Sekolah Perempuan* website has shown itself to be a successful instrument in encouraging women entrepreneurs to become financially independent. The initiative has successfully tailored digital marketing strategies to the specific needs, preferences, and behaviors of women, resulting in more meaningful engagement and improved outcomes.

CONCLUSION

This study emphasizes the critical role of a digital marketing platform in promoting women's financial independence, particularly through the *Sekolah Perempuan* website. The initiative has effectively addressed the specific needs of women by providing tools and resources that support financial self-sufficiency and empowerment. Based on the proposed design framework, three key elements are essential in developing an optimal women's empowerment program: (1) Promoting Women's Empowerment. This element is conducted through the implementation of educational empowerment, which consists of several components: self-confidence, financial literacy, and digital skills. The output expected is the Empowerment Center, which is an online platform where women receive continued access to education, mentoring, resources, and a supportive environment for personal and professional development; (2) Enhance digital marketing skills. This element focuses on developing two core competencies, such as digital skills (the component consists of Digital knowledge and Digital Security) and marketing skills (the component consists of Market Analysis, Market Planning, and Market communication). The output expected is Skill Development Center, which stresses how the *Sekolah Perempuan* Website could provide a program that could enhance the capacity on digital marketing, especially in developing both digital and marketing skills; (3) Support Financial Independence. This element focuses on integration media, including the Digital Marketing Platform and the Guiding Manual. The output expected consists of Marketing Tools Center (the component consists of User interface, Content Marketing, and Communication Features) and Support Center (the component consists of e-modules). This suggested Design framework is used to develop an optimal website in which every design framework component is implemented in each feature of the *Sekolah Perempuan* website. Assessing the effectiveness of the women's empowerment program enhanced by a digital marketing platform, the study reveals that several participants began earning income and reported increased confidence and financial independence. The statistical results also confirmed the program's positive impact, showing a significant mean difference and highly significant t-test results, which support the success of the initiative in fostering women's empowerment. The author

also suggested a study improvement, especially in conducting a similar study by designing a design framework that can be utilized on different digital platforms as part of an empowerment program.

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Tablet adoption and mobile learning impact in high school

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ABSTRACT

This study examines the challenges of integrating mobile learning and tablet adoption in Tshwane West high schools, where inconsistent device availability, infrastructure limitations, and varying digital confidence hinder effective use. It explored how educators prepare learners for mobile learning, the effectiveness of training programmes for tablet adoption, and strategies to optimize mobile learning. Using a qualitative approach, data were collected from nine educators across three urban and township schools through semi-structured interviews, classroom observations, and document analysis. Findings show generally positive attitudes toward tablets, with noted improvements in lesson delivery and student engagement. However, sustained integration requires reliable technology access, continuous educator-focused professional development, and robust technical and administrative support. The study recommends incorporating collaborative projects, quizzes with immediate feedback, and multimedia presentations in lessons to enhance learner motivation and performance. For future research, longitudinal studies are suggested to evaluate the lasting effects of mobile learning on academic outcomes and to investigate institutional and infrastructural barriers in varied educational contexts. These insights will inform more effective policies and practices to advance digital education transformation in South African schools.



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INTRODUCTION

The integration of mobile learning technologies, particularly tablet devices, in educational settings has rapidly increased over the past decade, driven by the promise of enhancing teaching and learning processes. Mobile learning offers the flexibility of accessing educational content anytime and anywhere, fostering interactive and student-centered pedagogical approaches (Cagiltay et al., 2015; Isaacs, 2012). In South Africa, educational policies have increasingly recognized the potential of Information and Communication Technologies (ICT) to bridge gaps in educational quality and access, aligning with the Department of Basic Education's 2030 vision to improve ICT proficiency among teachers and learners (DBE, 2020). However, the effective implementation of mobile learning remains uneven, especially in high schools located in diverse socio-economic contexts such as Tshwane West, where infrastructural limitations and varying levels of teacher readiness pose significant challenges.

Research urgency emerges from persistent inequalities in device availability, internet connectivity, and digital literacy skills, which can hinder the equitable adoption and impact of

mobile learning interventions (Mtebe & Raisamo, 2014). While some studies have explored general attitudes toward mobile technology use in South African classrooms (Ng'ambi et al., 2016; Jong et al., 2018), there remains a scarcity of localized, empirical investigations focusing specifically on the acceptance and practical effectiveness of tablet devices among high school teachers within the Tshwane West region. This gap is critical to address because teacher acceptance and proficiency directly influence the success of technology integration in pedagogy (Ifenthaler & Schumacher, 2016). Alternative solutions such as desktop-based e-learning platforms or purely online learning systems have been studied but often face limitations related to infrastructure and learner engagement in the South African context (Atilola et al., 2021). In contrast, mobile learning using tablets holds promise due to portability, ease of use, and the ability to support interactive and multimodal learning experiences (Sharples et al., 2016). Nonetheless, empirical data on how these benefits translate into classroom practice, especially in township schools with constrained resources, are limited.

The novelty of this research lies in its focused examination of both the effectiveness of mobile learning and the acceptance of tablet devices by teachers in Tshwane West high schools, utilizing qualitative methods including direct classroom observations and semi-structured interviews. While previous international and national studies have documented mobile learning adoption and its challenges broadly (Kukulska-Hulme & Shield, 2008; Scoot, 2023), this study differentiates itself by contextualizing teacher experiences and infrastructural factors within a tri-school setting representing urban and township environments. Previous studies emphasize the increasing demand and potential of integrating Information and Communication Technology (ICT) in South African classrooms to improve teaching and learning outcomes. For example, the study by Kgosi et al., (2023) in the Tshwane West District highlights that while ICT makes lessons more interesting and improves learner engagement, many educators experience challenges such as poor technical support, lack of adequate infrastructure, frequent power outages, and insufficient devices for all learners. The study also points out that educators employ team building as a strategy to implement ICT effectively, but infrastructural constraints like load shedding significantly hamper efforts. These findings underline persistent infrastructural and resource challenges that this study can further explore, especially in relation to mobile learning's effectiveness and device acceptance in resource-constrained environments.

Kgosi et al., (2023) investigated educators' views on the application of educational technologies in selected Tshwane West secondary schools and found that despite the Department of Basic Education's efforts to provide tablets, laptops, and smartboards, many teachers feel underprepared due to limited professional development opportunities and inadequate technical support. Their study revealed issues such as poor maintenance of educational technology, lack of relevant digital teaching materials, infrastructural limitations, including unreliable internet connectivity, and concerns about teacher readiness to integrate these technologies into pedagogical practices. These gaps point to the critical need for contextualized training and sustained technical support, themes that resonate with this study's emphasis on teacher preparedness and professional development in mobile learning.

Kgosi et al., (2023) studies complement this research by providing empirical evidence of the systemic challenges affecting ICT adoption in Tshwane West schools and highlighting gaps in teacher training, infrastructure, and resources. Kgosi et al., (2023) work emphasizes educator perceptions and readiness; this study narrows in on mobile learning and tablet acceptance specifically within high school contexts, incorporating theoretical frameworks such as the Technology Acceptance Model (TAM) and TPACK. This specificity allows this research to address the nuanced dynamics of mobile device acceptance and pedagogical integration more explicitly.

Therefore, this study fills an important gap by deepening the understanding of how educators prepare learners for mobile learning, the effectiveness of specific training programs on tablet acceptance, and by proposing targeted strategies for mobile learning optimization in high schools. By dovetailing with prior studies, this research offers critical insights relevant to policymakers, educators, and stakeholders aiming to realize sustainable mobile technology integration tailored to the unique infrastructural and socio-economic realities of South African public schools. It also

contributes to the field by providing nuanced insights into the real-world integration of tablets in curricula aligned to South Africa's CAPS framework, highlighting both opportunities and constraints that have not been extensively reported in prior research.

The objective of this study is therefore to investigate how effective mobile learning is in enhancing teaching and learning outcomes, and to assess the level of acceptance of tablet devices among teachers in Tshwane West high schools. Through this, the study aims to inform policy and practice concerning the strategic deployment of educational technology to foster equitable, quality education in South Africa. The research aims to answer important questions about the application and integration of contemporary mobile technologies into the educational environment of South African high schools. The focus of this study is on examining how educators get learners ready for mobile learning. This entails comprehending the teaching techniques and technology instruments that instructors use, such as interactive EduBoards, laptops, and tablets, to improve the educational experience. The research acknowledges that preparation includes not only the installation of devices but also the integration of digital citizenship instruction to give learners the fundamental abilities they need. For example, ethical conduct in online contexts, internet security, and personal data management. The goal is to emphasize how these preparation activities affect learners' participation and comprehension of course content in classrooms that use technology.

In addition to getting ready, the study examines the efficacy of training courses aimed at helping educators embrace mobile learning and accept tablets as instructional aids. It analyses formal initiatives by the Department of Basic Education, such as seminars and planned meetings, as well as the function of school-integrated Professional Learning Communities (PLCs), which encourage peer mentoring and cooperative learning. The focus is on how these courses help educators develop their technological, pedagogical, and content expertise, which in turn promotes their confidence and preparedness in incorporating these technologies. The study aims to ascertain the degree to which these training treatments result in practical classroom methods, while also pinpointing obstacles like huge class sizes. Resource restrictions and sizes that hinder consistent execution.

Last but not least, the study aims to propose strategic strategies for improving the efficient use of mobile learning. The necessity of upgrading and modernizing mobile technology laboratories to offer useful, accessible, and engaging learning environments is highlighted by these approaches. They also support thorough, ongoing professional development that is contextualized to the unique requirements of educators and schools and in line with national frameworks for digital learning competency. The study also emphasizes the necessity of ongoing pedagogical mentorship and technical assistance to ensure that educators stay motivated and competent throughout their careers. The study's goals are to provide useful insights that can inform infrastructure investment, policy creation, and educator training programs, with the aim of creating a just and equitable society. Resources-restricted instructional environments that support sustainable mobile learning ecosystems.

METHOD

Type of Research

The population for this study consisted of the thirty-eight (38) high schools located in the Tshwane West District of Gauteng Province, South Africa. These schools collectively represent the broader educational community from which relevant information about mobile learning and the acceptance of tablet devices was sought. The research targeted high schools actively engaged in the use of mobile learning technologies, particularly focusing on educators involved in teaching Grades 7 to 12.

From this population, a purposive sampling technique was employed to select three schools that met specific inclusion criteria: they offer Grade 7 to 12 instruction, actively implement mobile learning in their curricula, and serve as training centres for educators utilizing educational technologies. This intentional selection ensured that the sampled schools provided rich, relevant contexts for investigating the phenomenon.

Within each selected school, three educators were purposively chosen to participate in the study, resulting in a total sample size of nine teachers. These educators were selected to represent diverse subject streams, including general subjects, languages, mathematics, and science, thus capturing a range of perspectives related to mobile learning practices. The sampling approach focused exclusively on educators due to the study's emphasis on teacher experiences and readiness, intentionally excluding learners from the sample.

Overall, the purposive sampling design ensured that participants possessed direct, relevant experience with mobile learning technologies, enabling an in-depth qualitative exploration of their perceptions, practices, and challenges within their specific educational contexts. This approach facilitated comprehensive insights into the integration and acceptance of tablets and mobile learning in Tshwane West high schools.

Time and Place of Research

The research was conducted over a three-month period from March to May 2025. The study took place in three purposively selected high schools within the Tshwane West district in Gauteng province, South Africa. The use of purposive sampling in the study is justified due to several important reasons drawn from the research context and methodology described: the study aimed to investigate the effectiveness and acceptance of mobile learning and tablets specifically in high schools of Tshwane West. Purposive sampling allowed the researcher to deliberately select three schools that met particular inclusion criteria, such as providing instruction in Grades 7-12, actively using mobile learning in senior-phase instruction, and serving as training hubs for teachers on educational technology. This ensured the sample was highly relevant to the research questions. Three teachers were deliberately chosen from each school, representing general, language, Mathematics, and science subjects, focusing on educators knowledgeable and experienced in using mobile learning (a total of nine participants). This ensured data was collected from individuals with direct and relevant experience with the phenomena under study. The qualitative multiple case study approach required rich, in-depth data rather than statistically generalizable findings. Purposive sampling facilitated an intense, contextualized exploration of educator preparedness, training effectiveness, and strategic use of technology within actual school environments. The selection of Tshwane West District was also due to the researcher's residence in the area, enhancing access and the feasibility of data collection. Among the 38 schools in the district, only three met the set criteria for active mobile learning use and training roles, making purposive sampling an appropriate sampling strategy. The interpretive qualitative paradigm assumes reality is socially constructed and context-specific, so purposive sampling fits, as it aims to understand participants' subjective experiences deeply within their settings rather than aiming for statistical representativeness. Therefore, purposive sampling was employed strategically to select information-rich cases that directly address the research questions, enable detailed examination of mobile learning integration in relevant secondary school contexts, and ensure the feasibility and rigor of the qualitative study design. The schools included one urban school and two township schools representing different socio-economic quartiles (Quartile 3 urban, Quartiles 2 and 3 township schools), providing diverse contexts for data collection.

Research Targets and Objectives

The main objective of this study was to investigate how effective mobile learning is in improving teaching and learning in Tshwane West high schools and to assess the acceptance of tablet devices among teachers. Specific objectives included exploring teacher attitudes towards tablets, examining infrastructural support and constraints, evaluating pedagogical integration, and analysing student engagement as observed through mobile learning practices.

Research Subjects

The study includes all 38 high schools in the Tshwane West District of South Africa's Gauteng Province. These schools serve as the pool from which the sample schools were chosen for the study on the effectiveness of mobile learning and the acceptance of tablet devices. Purposeful sampling is the method utilized for sampling. The justification for this approach was that the

research sought to choose schools that satisfied certain requirements that were pertinent to the topic's targets. The schools were chosen using the following inclusion criteria: schools offering instruction for Grades 7 through 12, schools that actively use mobile learning in their senior-phase instruction, and schools serving as instructional technology training hubs for teachers.

For the reason that they met these requirements, just three schools were purposely chosen to make sure that students had direct experience with tablet device adoption and mobile learning. A total sample of nine educators was selected from each chosen school, representing three distinct subject streams: mathematics, science, language, and general topics. With this approach to sampling, participants were guaranteed to have real-world experience and pertinent knowledge of the subject being studied.

Because the study's goal was to acquire an in-depth understanding of specific contexts where mobile learning was actively used, rather than to draw general conclusions, purposive sampling was the way to go to every school in the district. This method made it possible to gain in-depth, context-specific understandings that were in line with qualitative case study techniques. The study employed purposive sampling to select participants, deliberately choosing teachers who actively use tablet devices in their classrooms and who had undergone CAPS-related mobile learning training. This intentional selection ensured that participants could provide rich, relevant data reflecting experienced use of mobile learning tools in varied school contexts. The sample comprised nine teachers drawn from three high schools in Tshwane West, representing a mix of urban and township environments (one urban school, two township schools of different socio-economic quartiles). This variation was purposeful to capture diverse infrastructural and socio-economic influences on mobile learning acceptance and effectiveness. Recruitment was facilitated through school management and the Subject Management Teams (SMTs), who identified teachers meeting the inclusion criteria and consented to participate. Sampling terminated upon reaching sufficient data saturation when additional interviews and observations no longer yielded new themes.

Procedure

Data collection began with securing permission from school management and the relevant educational authorities. Following ethical clearance and informed consent processes, semi-structured interviews were conducted with the teachers to probe their perceptions, acceptance levels, and experiences with mobile learning and tablet use. Direct classroom observations were scheduled to document actual tablet usage, pedagogical practices, and student engagement during lessons. Additionally, document analysis and open-ended questionnaires complemented the qualitative data, enabling triangulation of findings. Below is the research procedure.

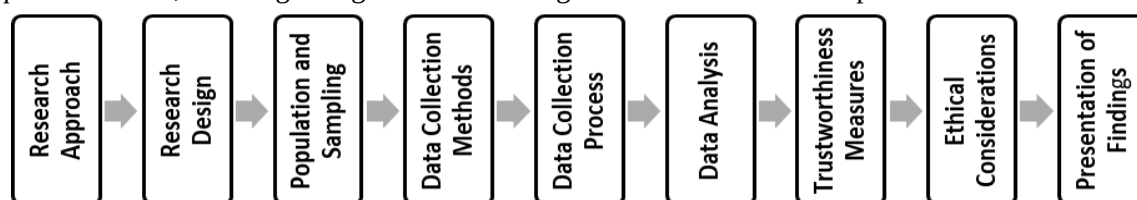


Figure 1. Research Procedure Chart

Data Collection Techniques and Instruments

Multiple qualitative instruments were utilized to collect data, namely, Semi-structured interviews: Developed to explore teachers' attitudes, challenges faced, training received, and perceptions of mobile learning effectiveness. The guide focused on indicators such as digital competence, troubleshooting skills, and integration strategies. Classroom Observation: Focus areas included device usage frequency, pedagogical integration, classroom management during tablet use, infrastructure challenges (connectivity and power), and student interaction. Specific observable indicators were identified to ensure systematic data gathering. Document analysis: School policies, maintenance records, and digital resource inventories were reviewed to

contextualize infrastructural support, and finally, Open-ended questionnaires provided additional qualitative data on teachers' self-reported experiences and perceptions.

Data Analysis Techniques

The collected data were analysed using thematic content analysis. Interview transcripts, observation notes, and document excerpts were coded iteratively to identify recurring themes related to mobile learning effectiveness and tablet acceptance. Data segments were categorized under emergent themes such as teacher digital competence, infrastructural barriers, pedagogical practices, and student engagement. Constant comparison methods were employed to validate findings across data sources, enhancing credibility and dependability. Reflexive journaling and peer debriefing sessions were also conducted to maintain research trustworthiness, ensuring confirmability and consistency of interpretations.

To add a comprehensive research instrument table that aligns with the research questions, data collection instruments, applicable frameworks, and emerged themes from the study, the following [Table 1](#) can be constructed using the detailed methodology and thematic focus described in the document:

Table 1. Research Instrument

No.	Research Question	Data Collection Instrument	Applicable Frameworks	Emergent Themes/Focus Areas
1	How do educators prepare learners for mobile learning?	Document Analysis, Non-participant Observation	Technology Acceptance Model (TAM), TPACK	Use of EduBoards, laptops, and tablets in lessons; Digital citizenship instruction; Lesson planning and preparation
2	How effective are training programmes to assist educators with mobile learning and the acceptance of tablet devices?	Semi-structured Interviews, Open-ended Questionnaires	TAM, TPACK	Attendance at DBE training workshops, Professional Learning Communities (PLCs), and the Integration of mobile learning in classrooms
3	Which strategies can be put in place for the effective use of mobile learning?	Open-ended Questionnaires	TAM, TPACK	Renovation of mobile labs; Comprehensive teacher training and ongoing support; Infrastructure and policy support

This table synthesizes the study's research questions with the instruments used to gather data, the theoretical frameworks guiding the analysis, and key thematic findings related to each question.

Data Security

To protect participant confidentiality and maintain the integrity of data, multiple security protocols were implemented throughout the research process. All participants were assigned numeric codes and pseudonyms in transcripts and reports to anonymize identifying information. Audio recordings of interviews were stored securely on a password-protected computer accessible only to the principal researcher and supervisors. Digital files were regularly backed up using encrypted storage. Physical documents, including consent forms and observation notes, were locked in a secure cabinet within the researcher's office. Data access was strictly limited to the research team, and any data shared in presentations or publications omitted personal identifiers. After completion of the study, audio recordings and sensitive data will be permanently deleted in accordance with institutional data retention policies.

Ethical Considerations

Ethical approval was duly obtained from the Tshwane University of Technology Research Ethics Committee before commencing the study. Permission to conduct research within the schools was secured from the Department of Basic Education and the relevant School Governing Bodies (SGBs). Participation was entirely voluntary, with teachers informed of their right to withdraw at any time without penalty. Before data collection, informed consent was obtained in writing, detailing the purpose of the study, procedures, confidentiality assurances, and intended dissemination of findings. The researcher was sensitive to power dynamics, ensuring that participation decisions were free from coercion or undue influence. During classroom observations, efforts were made to minimize disruption, and participants' and learners' anonymity was respected by not including personal data or identifiable images. Ethical principles of beneficence, respect, and justice guided all interactions, safeguarding the dignity and rights of participants throughout the study.

RESULTS AND DISCUSSION

Results

The study's results on the effectiveness of mobile learning and the acceptance of tablet devices among teachers in Tshwane West high schools revealed several key themes. This study aimed to explore and understand the use of mobile learning and tablet acceptance among educators in Tshwane West high schools. The objectives of this study were to determine how educators prepare learners for mobile learning, to assess the effectiveness of training programs designed to assist educators with mobile learning and tablet device acceptance, and to recommend strategies for the effective use of mobile learning in schools.

The study involved nine high school teachers selected from three purposively sampled schools in Tshwane West. The participants represented a mix of genders, ages, qualifications, and teaching experience:

Table 2. Biographical Information, Showing that All Respondents had Participated in Mobile Learning Training Programs

No.	Teacher	Gender	Age Range	Years Teaching	Qualifications	Attended Mobile Learning Training
1	A	Female	30-35	7	B.Ed (Computer Sciences) HONS	Yes
2	B	Female	30-35	7	B.Ed (Computer Sciences) HONS	Yes
3	C	Female	50-55	23	B.Ed (FET)	Yes
4	D	Female	25-30	6	B.Ed (FET)	Yes
5	E	Male	45-50	17	B.Ed (GET)	Yes
6	F	Male	25-30	6	B.Ed (Mathematics)	Yes
7	G	Male	45-50	11	B.Ed (Physical Sciences)	Yes
8	H	Female	35-40	10	B.Ed (Technology Education)	Yes
9	I	Female	55-60	24	B.Ed (English)	Yes

While gathering the necessary data, these are some of the responses given by the participants: Teacher A emphasized how tablets facilitate learning through interactive apps that support instant feedback and corrections. Teachers B and C noted that mobile learning makes teaching easier by enabling engagement even when learners are off-premises and by providing more interactive, personalized learning experiences. Teacher E explained the use of AI-enhanced editing exercises learned in workshops and implemented with learners. Teacher H described using gamification via tablets and EduBoards to make mathematics lessons more engaging and fun. These responses showed that educators are willing to use mobile learning, and some responded that it made teaching easier.

Teacher Acceptance and Digital Competence

Teachers generally exhibited positive attitudes toward the use of tablets in the classroom. All participants had received CAPS-aligned mobile learning training, equipping them with the basic digital competence necessary for integrating technology into their teaching. Teachers reported that tablets improved lesson delivery by providing interactive and up-to-date content, which promoted more student-centred instructional approaches. However, some teachers expressed occasional discomfort with troubleshooting technical issues, indicating a need for ongoing professional development to enhance digital confidence.

Infrastructure and Device Availability

The availability of devices was inconsistent across the schools. Urban schools had comparatively better access to tablets and more reliable infrastructure, while township schools faced significant challenges such as limited device numbers, unreliable internet connectivity, and frequent power outages. These infrastructural constraints limited the regular and effective use of tablets in classrooms, especially in township settings. Maintenance of devices was reported as irregular in some schools, further impacting device usability during lessons.

Pedagogical Integration and Usage

Teachers who effectively integrated tablet use with traditional teaching methods, such as group discussions and interactive applications, observed higher student engagement. Tablets were used for diverse purposes, including immediate feedback, collaboration among students, and multimedia content delivery. Nonetheless, some teachers faced difficulties shifting from textbook-reliant teaching to digitally enhanced instruction, which affected the consistency and depth of mobile learning integration.

Student Engagement and Academic Outcomes

Most teachers observed increased student engagement when tablets were part of the lesson, particularly in science and technology subjects that benefited from interactive digital content. There was a perception of improved academic performance associated with mobile learning, though this was tempered by the irregular availability of devices. In addition, classrooms leveraging mobile learning reported better attendance and more timely submission of learning tasks, suggesting positive motivational effects of tablet use.

Discussion

This study aimed to investigate the effectiveness of mobile learning and the level of acceptance of tablet devices among teachers in Tshwane West high schools. The data revealed a generally positive perception of tablets as teaching tools, affirming that mobile learning has considerable potential to enhance instructional quality and student engagement. The teacher's point of view affects classroom technology. Given its potential for pedagogical benefit, looking at the digital world would not be unexpected ([Sulistyaningtyas, 2024](#)). These findings align with prior research emphasizing mobile learning's role in fostering interactive and learner-centred pedagogy ([Junior, 2025](#)). Teachers' acceptance was closely linked to their digital competence, consistent with [Ifenthaler & Schumacher \(2016\)](#) assertions that teacher readiness significantly affects technology integration success.

The positive attitudes toward tablet use underscore that once teachers receive proper CAPS-aligned training and develop foundational ICT skills, they are more inclined to incorporate digital tools effectively. This corroborates findings by [Dahri \(2023\)](#), who observed that adequate training boosts teacher confidence and adoption rates. However, despite the affirmative outlook, the study also highlights practical challenges, most notably, infrastructural deficits such as device shortages, unreliable internet connectivity, and frequent power outages in township schools. These barriers limit equitable access to mobile learning and constrain its consistent application, echoing concerns raised by [Mtebe & Raisamo \(2014\)](#) about infrastructural inequalities in African educational contexts.

The differences between urban and township schools in device availability and infrastructure suggest systemic inequities in resource distribution, which can perpetuate educational disparities

(Chikwe, 2024). This is a critical issue for educational administration and policy planning, indicating that without targeted investment in physical and digital infrastructure, mobile learning initiatives risk deepening rather than bridging educational gaps. In particular, the study's findings stress the need for sustainable infrastructure development plans that prioritize schools in lower socio-economic contexts, a concern aligned with South Africa's national strategies for education equity (DBE, 2020).

Pedagogically, the successful integration of tablets involved hybrid approaches where digital tools complemented traditional teaching methods, consistent with Isaacs (2012) emphasis on blended learning models. Teachers who combined tablets with group discussions and interactive apps observed enhanced student engagement and participation (Ahshan, 2021). This suggests that mobile learning is most effective when embedded thoughtfully within established instructional frameworks rather than used in isolation. Nonetheless, some teachers reported difficulty in moving away from textbook-centred pedagogy, indicating that ongoing professional development should focus not just on technical skills but on innovative pedagogical strategies that leverage mobile learning affordances.

Increased student engagement and improved academic outcomes in classes utilizing tablets point to positive motivational and cognitive effects, supporting evidence from Kukulska-Hulme & Shield (2008) who link mobile technology with active learning enhancement. The observed improvements in attendance and timely task submission may reflect higher student interest and accountability fostered by more interactive and relevant learning experiences. These findings contribute to academic economics by highlighting that investments in mobile learning can yield tangible educational benefits, potentially leading to better learner performance and retention, which are vital indicators of return on investment in educational technologies (Ghoulam & Bouikhalene, 2024).

From an educational leadership and management perspective, these results underscore the importance of holistic support structures comprising infrastructure, teacher development, and technical support to realize mobile learning's full potential. Educational leaders must ensure that schools have not only the devices but also reliable maintenance services and connectivity solutions. Furthermore, the involvement of stakeholder groups such as School Management Teams (SMTs) and School Governing Bodies (SGBs) in resource allocation and planning is paramount, as the study shows the value of collaborative governance in sustaining technology integration efforts.

Despite the insightful contributions, this research has limitations. The qualitative design and relatively small purposive sample of nine teachers from three schools, while providing rich contextual data, limit the generalizability of results beyond Tshwane West. Future research could employ mixed methods with larger, more representative samples to quantify mobile learning impacts and acceptance across more diverse school contexts. Additionally, this study did not include student perspectives or longitudinal measures of academic outcomes, which would provide further validation of the effectiveness noted by teachers. Investigating these areas could deepen understanding of mobile learning's broader educational effects.

There are several implications for practice and future research. Policymakers should prioritize addressing infrastructure inequalities and provide sustained, context-sensitive professional development that moves beyond technical training to include pedagogical innovation. Educational managers need to establish ongoing support mechanisms for device maintenance and troubleshooting to reduce classroom disruptions, thereby promoting more reliable use of mobile learning tools. Future research should explore scalable models of teacher training and infrastructural investment that can be adapted for other districts with similar socio-economic challenges.

In conclusion, this study contributes nuanced empirical insights into the realities of implementing mobile learning and tablets in a South African high school context marked by socio-economic and infrastructural disparities. It reinforces the critical interplay between teacher acceptance, infrastructural readiness, and pedagogical practice for effective technology integration. By illuminating both the promise and persistent barriers of mobile learning in Tshwane West, the findings provide valuable guidance for educational administrators, policy planners, and researchers

aiming to advance equitable, technology-enhanced education across South Africa and comparable contexts.

CONCLUSION

Based on the investigation of the effectiveness of mobile learning and the acceptance of tablet devices among teachers in Tshwane West high schools, it can be concluded that mobile learning is perceived as a valuable pedagogical tool that enhances student engagement and supports more interactive and student-centred teaching approaches. The findings show that teachers generally accept and appreciate the use of tablets, recognizing their potential to improve lesson delivery and motivate learners. However, the full benefits of mobile learning are constrained by infrastructural challenges, including inconsistent access to devices, unreliable internet connectivity, and power interruptions, particularly in township schools. Teacher digital competence, while adequately established through CAPS-aligned training, requires ongoing development focusing on both technical skills and innovative integration strategies to maximize tablet use in instruction. Operationally, this study suggests that educational policymakers and school leaders should prioritize investments to ensure equitable access to functional digital devices and stable connectivity across all schools in the region. Additionally, sustained and context-sensitive professional development programs are essential to empower teachers with both the confidence and pedagogical expertise needed for effective mobile learning implementation. Furthermore, establishing dedicated technical support systems will minimize classroom disruptions caused by device malfunction or connectivity issues. By addressing these factors, the educational system can more fully realize the transformative potential of mobile learning, advancing South Africa's goals for ICT proficiency and contributing to more equitable, quality education in high schools. Several recommendations for further research based on the study are to find best practices for increasing teacher capacity, evaluate the effectiveness and influence of several professional development strategies, including contextualized, mixed, and peer-supported ones. Study how variations in classroom size, infrastructure quality, teacher readiness, and socio-economic factors influence mobile learning adoption and effectiveness in diverse educational settings. Design and validate assessment instruments and training materials that are culturally and contextually relevant for mobile learning in South African and similar resource-constrained schools.

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The effect of the self-directed learning (SDL) model integrated with peer teaching on environmental literacy

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ABSTRACT

The escalating environmental issues in Indonesia highlight the need for early environmental education to cultivate environmental literacy, defined as a crucial attitude of environmental awareness, among students. An effective approach to cultivating environmental awareness through education is the Self-Directed Learning (SDL) model integrated with peer teaching, as this combined independent and collaborative method enhances students' sensitivity and independence in environmental problem-solving. This research aims to analyze the effect of implementing the SDL (Self-Directed Learning) model integrated with the peer teaching method on students' environmental literacy levels in the topic of environmental change. The research method employs a quantitative approach with a quasi-experimental design. The research sample consists of 36 students obtained through simple random sampling. The results of hypothesis testing indicate that the integration of SDL and peer teaching significantly contributes to improving students' environmental literacy. These findings imply that collaborative and independent approaches in learning can enhance students' understanding of environmental issues more effectively. Therefore, it can be concluded that the integrated SDL and peer teaching model can be applied to the topic of environmental change to foster students' environmental literacy. This study provides a foundation for future research to further develop the Self-Directed Learning (SDL) model integrated with peer teaching, exploring its application with diverse media and teaching materials across various subjects.



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INTRODUCTION

The environment is a crucial component that supports the sustainability of all life forms on Earth, which is where the interaction between biotic and abiotic components occurs. This creates an essential dependence between humans and the environment so that the two cannot be separated (Santi et al., 2018). Human activities that are not balanced with environmental awareness have been proven to significantly reduce the quality of the environment with a large level of concern (Prastiwi et al., 2020). Environmental issues are currently the focus that attracts the attention of many parties because of their potential threat to Indonesia (Santoso et al., 2021). However, the awareness of the Indonesian people on environmental issues is still low. Based on data from the Central Statistics Agency (2018),

the Environmental Indifference Behavior Index (IPKLH) in Indonesia was recorded at 0.51 in 2017, indicating a significant level of environmental indifference.

The habits of students who do not show concern for the environment can be assumed to indicate a low level of environmental literacy (Ahmadi, 2022). Environmental literacy is a very important ability for students in the 21st century, which should be instilled early in the school environment (Nariswari et al., 2022; Nugraha et al., 2021). Environmental literacy consists of 3 aspects, namely (1) cognitive, which includes knowledge of environmental issues and problems; (2) affective, regarding awareness and sensitivity to the environment; and (3) behavior, including the intention and ability to participate in determining responsible behavior in overcoming environmental problems (Fang et al., 2022).

The implementation of environmental literacy in learning activities in schools can be applied by providing knowledge about the environment and building awareness and sensitivity to the environment (Hayati, 2020). The implementation of environmental literacy in schools must also consider various essential aspects, including sensitivity to the surrounding environment, motivation, responsibility in decision-making, and active cooperation and involvement (Aswita et al., 2022). One of the learning models that can be chosen is the Self-Directed Learning (SDL) model, integrated with peer teaching methods to achieve independent and collaborative learning.

The Self-Directed Learning (SDL) model, according to Garrison, is a self-directed learning approach that requires initiative from students and, in practice, helps in developing self-management, monitoring, and student motivation (Palupi et al., 2023). The peer teaching method involves interaction between students in the exchange of information and opinions, which encourages collaboration between them (Kuslulat, 2023). According to research conducted by Kemp et al., (2022), the peer teaching method is known to support the implementation of the Self-Directed Learning model. The study shows that this approach can increase confidence and cooperation between students. In addition, research conducted by Yoo et al., (2017) stated that Self-Directed Learning using peer teaching can be effective in increasing confidence, performance, and learning satisfaction.

Based on previous research, the application of the SDL model integrated with peer teaching methods can increase deep understanding, awareness, independence, motivation, sense of responsibility, active participation, and critical thinking skills in solving problems (Baharuddin et al., 2022; Kuslulat, 2023; Purwaningsih & Widodo, 2023). However, no study has explicitly investigated the synergy between self-directed learning models and peer collaboration, specifically within the context of enhancing students' environmental literacy. This research will apply the SDL model that is integrated with peer teaching methods in learning about environmental change. This approach is expected to be able to encourage increased awareness and independent ability of students to explore the topics they want to learn in the context of solving environmental problems. In addition, through this process, it is hoped that it can also increase the motivation and responsibility of students to collaborate in dealing with environmental problems. By applying the SDL model that integrates peer teaching methods, it is hoped that students' environmental literacy can increase.

METHOD

This research was conducted by the quasi-experimental method with a nonequivalent control group design. The research process involves the provision of pre-test and post-test using environmental literacy test instruments, which are applied to the experimental class and control class. The design of the study is presented in Table 1.

Table 1. Nonequivalent Control Group Design

No.	Class	Pre-test	Treatment	Post-test
1	Experiment	O1	X	O2
2	Control	O3	C	O4

(Sugiyono, 2019)

O1-O3 is the value of the Pre-test Environmental literacy of students in the experimental class and control on environmental change materials. O2-O4 is the value post-test Environmental literacy of students in the experimental class and control on environmental change materials. X is the treatment of experimental classes with the SDL model integrated with peer teaching methods. C is the treatment of control classes with the SDL learning model.

The research, which was carried out from January 2024 to July 2024 at Senior High School 18, Bekasi City, was given to 72 students in class X, with 36 students in class X-1 as the experimental class and 36 students in class X-2 as the control class. This research began by providing a pre-test to students to measure their initial ability in environmental literacy related to environmental change materials. Then, the learning process of environmental change material was carried out by applying the SDL model integrated peer teaching method in the experimental class and applying the Self-Directed Learning (SDL) model only in the control class. After being given treatment, students will then be given a post-test to measure their environmental literacy skills after learning has taken place.

Pre-test and post-test have been tested for validity and reliability calculations previously. The environmental literacy instrument's validity was tested using Pearson's Product-Moment Correlation, comparing the calculated r-count with the table r-table. The validity test criterion was: if r-count > r-table, the research instrument was considered valid; if r-count < r-table, the research instrument was considered invalid (Darma, 2021). Based on the results of the validity test it shows that all questions on the tested instrument are valid. The environmental literacy instrument's reliability was tested using Cronbach's Alpha formula:

$$r_{11} = \left[\frac{k}{k-1} \right] \left[1 - \frac{\sum \sigma_b^2}{\sigma_t^2} \right] \quad (1)$$

Information:

r_{11} : Instrument reliability coefficient

k : Number of valid question items

$\sum \sigma_b^2$: Number of question item variants

σ_t^2 : Total number of variants

According to Saputra et al., (2022), reliability values can be observed using the reliability index presented in Table 2. Based on the results of the reliability test, it shows that the questions on the tested instrument are reliable with a very high reliability index.

Table 2. Reliability Index

No.	r_{11} value	Information
1	0.00 – 0.20	Very low
2	0.21 – 0.40	Low
3	0.41 – 0.70	Enough
4	0.71 – 0.90	High
5	0.91 – 1.00	Very high

The data obtained from the pre-test and post-test results were analyzed to evaluate the effect of the SDL model integrated with the peer teaching method on environmental literacy. The analysis process involves prerequisite tests, namely normality tests and homogeneity tests, before proceeding to hypothesis tests at a significance level of 0.05. In addition, the improvement of environmental literacy was also analyzed using the normalized gain test.

RESULTS AND DISCUSSION

Results

Students' environmental literacy was measured based on data obtained from the results of pre-tests and post-tests conducted in the experimental class and control class. The description of the environmental literacy test data can be seen in Table 3.

Table 3. Description of Environmental Literacy Test Data

No.	Data	Experimental Classes		Control Classes	
		Pre-Test	Post-Test	Pre-Test	Post-Test
1	Maximum Value	74.00	100.00	71.00	99.00
2	Minimum Values	42.00	77.00	41.00	71.00
3	Average	57.50	90.14	56.56	84.75
4	Standard Deviation	7.15	6.22	7.15	7.10
5	Average Gain Score		32.64		28.19

Based on the data in [Table 3](#), the experimental class showed a more significant increase in values compared to the control class. The average score of the pre-test of the experimental class was recorded at 57.50 and increased to 90.14 in the post-test. Meanwhile, the control class had a pre-test average of 56.56, with an increase in the post-test average to 84.75. The average environmental literacy of students based on various aspects of environmental literacy can be seen in detail in [Table 4](#).

Table 4. Average Score Criteria Based on Environmental Literacy Aspects

No.	Aspects	Experimental Classes				Control Classes			
		Pre-Test	Criterion	Post-Test	Criterion	Pre-Test	Criterion	Post-Test	Criterion
1	Cognitive	60.86	Enough	91.83	Very High	60.83	Enough	87.11	Very High
2	Affective	50.62	Very Low	86.33	Very High	49.26	Very Low	78.92	Tall
3	Behavior	66.11	Enough	96.11	Very High	62.04	Enough	93.70	Very High

Based on the data in [Table 4](#), it is known that in both classes, the environmental literacy aspect that obtained the highest results was the behavior aspect. Meanwhile, the environmental literacy aspect that obtained the lowest results was the affective aspect. However, based on these data, the experimental class showed a significant improvement. This can be seen in the affective aspect of the experimental class in the post-test result of 86.33, which is categorized as very high.

The data obtained was then tested and analyzed to determine the effect of the SDL model integrated with the peer teaching method. The analysis test was carried out using a hypothesis test with an independent sample t-test. The results of hypothesis testing can be seen in [Table 5](#).

Table 5. Independent Sample T-Test Results

	t Independent	Sig. (2-tailed)	Interpretation
Gain Score	2.814	0.006	The value of Sig. (2-tailed) < 0.05,

Based on [Table 5](#). The results of the Independent Sample T-Test in the post-test result data were obtained, $0.006 < \alpha$ value of 0.05, which can be assumed that the SDL model integrated with the peer teaching method significantly affects students' environmental literacy. Then, to determine the effectiveness of the integrated SDL model of the peer teaching method, a normalized gain test was carried out, which can be seen in [Table 6](#).

Table 6. Normalized Gain Test Results

No.	Class	N-Gain	Criteria
1	Experiment	0.78	High
2	Control	0.65	Medium

Based on [Table 6](#), the normalized gain test result in the experimental class was 0.78, which was greater than the normalized gain test result in the control class, which was 0.65. These results can mean that the SDL model integrated with the peer teaching method used in the experimental class is effective with a high category of students' environmental literacy. Meanwhile, the control class that uses the SDL model alone is less effective against students' environmental literacy.

Discussion

Based on the results of the study, the pre-test score showed that the initial ability of both classes was low but balanced. After the treatment was given, the experimental class experienced a significant increase in post-test scores compared to the control class. These findings indicate that the SDL model integrated with peer teaching methods is more effective in improving environmental literacy, especially in the aspects of cognitive, affective, and behavioral. The results of data analysis through an independent sample t-test and a normalized gain test support this conclusion, with the rejection of H_0 and the N-Gain value of the experimental class of 0.78, which is higher than the control class of 0.65. Thus, it can be concluded that the application of the SDL learning model integrated with the peer teaching method has a positive and effective effect on improving students' environmental literacy.

Based on the cognitive aspect of environmental literacy, the application of the SDL model integrated with the peer teaching method can increase students' understanding of the concepts and issues of environmental change. The planning, monitoring, and evaluation stages of learning increase students' activeness in searching, analyzing, and interpreting knowledge about environmental issues and problems (Putri et al., 2019). Interaction and giving feedback between students also contribute to supporting a deeper and more comprehensive understanding of various environmental issues (Aswat, 2019; Putri et al., 2023).

Based on the affective aspect, the application of the SDL learning model integrated with the peer teaching method can develop students' attitudes and concerns about the environment. The learning process that involves students actively in designing and evaluating learning, as well as interaction and feedback from fellow students, can train a sense of responsibility and trigger a sense of concern and a positive attitude towards the environment. This indicates that applying the SDL model integrated with peer teaching methods can develop students' emotions and attitudes toward the environment in the form of a sense of responsibility and environmental concern (Sumarno, 2020; Wali et al., 2020). Then, based on the behavioral aspect, this learning model can encourage the application of knowledge and positive attitudes that have been learned towards the environment in daily life. This stage can help students in identifying and overcoming environmental problems, and interactions between students can support and inspire each other in implementing pro-environmental behavior (Amaliyah et al., 2019; Ardhiyansyah et al., 2023).

The application of the SDL learning model integrated with the peer teaching method in the experimental class was carried out very well. The syntax of the SDL learning model integrated with the peer teaching method is divided into 5 stages, namely readiness trigger, setting goals, group tutor discussion, peer teaching, and learning evaluation. At the readiness trigger stage, students are given stimuli in the form of articles about news about environmental change issues that are happening. According to the research of Laine et al., (2021), readiness to conduct Self-Directed Learning is indispensable to determine the level of initiative, independence, responsibility, confidence, and motivation of students. In addition, in the implementation of the integrated SDL model, the peer teaching method requires self-management, self-monitoring, and motivation. Providing articles in the form of news on environmental change issues can trigger students' readiness to see problems as challenges so that they can find solutions and be more motivated to learn about it (Riyaningrum & Kusumawati, 2019).

Students will be divided into small groups to make a learning contract at the goal-setting stage. The learning contract includes the preparation of learning objectives, material selection, tutor determination, scheduling, and the search for learning resources. The readiness built in the previous stage can hone students' prior understanding (Laine et al., 2021). This stage trains students to take initiative and be responsible in managing their own learning (Putra et al., 2017; Suroto et al., 2022). The opportunity to design their learning can also encourage the improvement of students' critical thinking skills (Baharuddin et al., 2022). So, at this stage, students can be trained in terms of taking responsibility for solving environmental problems.

The learning objectives in the learning contract that have been made by the students will be realized in the third and fourth stages. In the third stage, namely the group tutor discussion stage, students will gather with the tutor group. The tutor group consists of students who are tutors on the

same material. In the group discussion of tutors, students will be given worksheets that need to be filled out by everyone by discussing together (Pratama et al., 2021). In addition, with tutor group discussions, students who act as tutors can convey ideas and explore information more freely and comfortably (Aswat, 2019). At this stage, students as tutors must understand the material that has been selected well in the group as a provision before delivering the material to the original group.

After the group discussion, students peer-teach the original group. In peer teaching, students convey the material they learn to their peers, increasing their deep understanding of the environment because the equality of language and communication created can help students receive material, and students are also freer to ask their tutors (Irfan et al., 2024). Peer teaching trains students' independence and responsibility, as well as improving abilities in the cognitive, affective, and psychomotor domains, in line with aspects of environmental literacy (Yusup & Sari, 2020). The final stage is the learning evaluation, which evaluates learning outcomes. Students fill out a self-reflection table based on the suitability of learning with the learning contract. This evaluation is to assess student achievement according to the learning contract. Self-evaluation and peer evaluation play a role in improving students' cognitive abilities and motivation (Nurhardini, 2017). This finding is in line with the research of Idrus (2019), which states that evaluation can significantly increase students' motivation to learn.

The conclusion of the discussion shows that the application of the SDL learning model integrated with the peer teaching method in the experimental classroom has a more effective effect on improving students' environmental literacy. This learning model allows students to design, implement, and evaluate the learning process. In addition, students can exchange knowledge, information, and experience, which allows them to understand environmental concepts in more depth.

CONCLUSION

Based on the result, it can be concluded that the SDL learning model integrated with the peer teaching method has an effect on students' environmental literacy. Thus, the implication of this research is that this learning model can be used as an effective alternative for teachers to enhance students' environmental literacy when teaching environmental change material. Additionally, this study can serve as a foundation for future research, developing the Self-Directed Learning (SDL) model integrated with peer teaching by incorporating more varied media and teaching materials, and applying it to other learning subjects.

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Implementation of TBL with constructivist and discovery learning approaches to enhance eco-literacy of homeschooling students

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ABSTRACT

The escalating ecological crisis demands an immediate educational response, especially for younger generations. Eco-literacy, the ability to understand ecological systems, think critically about environmental issues, and adopt responsible behaviors, needs to be cultivated early through contextual and transformative learning. This study explores the implementation of a Technology-Based Learning (TBL) model, grounded in constructivist and discovery approaches, to enhance eco-literacy among homeschooling students aged 10–13 years. Using a descriptive qualitative case study, three homeschooling students and two parents at Rumah Ulin, a family-based learning environment integrating ecological values and digital technology, participated as informants. Data were collected retrospectively through participant observation, semi-structured interviews, student reflections, and documentation of prior learning activities. Findings show significant development in four eco-literacy dimensions: ecological awareness (recognition of human–environment relationships), environmental knowledge (understanding of concepts and issues), ecological attitudes (care, responsibility, and commitment to sustainability), and ecological actions (environmentally friendly practices such as reducing plastic use and managing waste). These results demonstrate that technology-based, learner-centered strategies can foster meaningful ecological understanding in non-formal contexts. Future research with larger, more diverse participants and longitudinal designs is recommended to strengthen generalizability and assess long-term impacts.

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INTRODUCTION

The global environmental crisis is increasingly threatening the sustainability of ecosystems and the survival of humankind. Various serious issues have emerged, such as deforestation to meet market demands, soil and water pollution caused by waste cooking oil disposal and the use of synthetic detergents, air pollution resulting from vehicle emissions and cigarette smoke, as well as the accumulation of plastic waste in various places. The impacts of these problems are not only felt by the present generation but also endanger the well-being of future generations. In this context, ecological education is no longer merely an option but an urgent necessity that must be instilled from an early age in children's education.

Eco-literacy is one of the key concepts in ecological education, encompassing awareness of environmental issues, ecological knowledge, a caring attitude, and the ability to take action in everyday life. This concept consists of four main dimensions: ecological awareness, environmental

knowledge, ecological attitudes, and ecological actions (Disinger & Roth, 1992; Hollweg et al., 2011). These dimensions integrate cognitive, affective, and psychomotor aspects to shape a holistic understanding of the relationship between humans and nature.

Along with the advancement of technology, digital-based learning approaches hold great potential to strengthen environmental literacy outcomes. Recent studies Hajj-Hassan et al., (2024) indicate that digital media such as videos, simulations, and online platforms can enhance the understanding of sustainability, especially when combined with reflective and contextual learning. The theory of connectivism emphasizes that the interconnectedness between learners, digital tools, and real-world issues serves as an essential foundation in 21st-century learning design.

A learning model that integrates ecological values with technology can be applied both in formal schools and in non-formal education. One increasingly popular form of non-formal education is homeschooling, which offers high flexibility and allows for a more personalized and contextual learning process. For example, *Rumah Ulin*, a homeschooling community in Indonesia, combines ecological values with the use of technology through various sustainability projects, such as processing used cooking oil into soap and converting organic waste into an eco-enzyme. Knowledge and skills related to these processes are largely acquired through digital resources such as video tutorials, e-books, and online forums, which not only support learners' understanding but also create opportunities to develop online classes on used cooking oil processing and organic waste utilization. This approach demonstrates how technology can expand the reach of practical, environmentally based learning to a broader audience.

However, despite its great potential, research on the application of Technology-Based Learning (TBL) to enhance eco-literacy in homeschooling in Indonesia remains very limited. Most previous studies have focused on formal schools or examined TBL and environmental education separately (Ninsiana et al., 2024). In contrast, global trends show significant growth in homeschooling in developed countries, where technology integration has supported science and environmental literacy (Hernholm, 2024). Compared to the global context, this approach holds unique characteristics in developing countries such as Indonesia, where access to technology varies and contextual learning practices place greater emphasis on family and community involvement.

Therefore, this study addresses the existing gap by integrating Technology-Based Learning (TBL) through a blended learning approach with constructivist and discovery learning strategies to foster eco-literacy among homeschooling students aged 10–13. This model not only emphasizes cognitive aspects but also activates critical thinking and problem-solving skills through hands-on practices supported by technology.

The novelty of this research lies in two key aspects: (1) the exploration of TBL within the homeschooling context in Indonesia, which has rarely been highlighted in the literature, and (2) the integration of TBL with constructivist and discovery learning strategies to support technology-based ecological education. The contributions of this study include: (1) Theoretical aspect: expanding the body of research on technology-based learning in non-formal education and among adolescents, which has received relatively little attention. (2) Practical aspect: providing implementation guidelines for other homeschooling communities in Indonesia, which can also be adapted to formal schools facing similar challenges in strengthening eco-literacy. This study is also relevant for the development of sustainability-oriented learning models at the global level, particularly in developing countries that face infrastructure limitations yet are rich in local contexts that support environmentally friendly practices.

METHOD

This study employs a descriptive qualitative approach with a single case study design to examine the implementation of Technology-Based Learning (TBL) in enhancing eco-literacy within a non-formal education context, namely *Rumah Ulin*, a family-based homeschooling community. The case study method allows for an in-depth exploration of the dynamic relationships between learners, technology, and ecological learning practices. In qualitative research, even a

single participant can serve as a valid data source if they provide deep contextual insights that are relevant to the phenomenon under investigation (Arikunto, 2010).

This study focuses on participants with extensive reflective experience in applying TBL strategies within a homeschooling environment, particularly in fostering eco-literacy. Part of the data was collected retrospectively by reconstructing the learning experiences of students aged 10–13. Although two of the three participants were 14 and 17 years old at the time of data collection, they had been actively involved in TBL-based learning during the targeted age range. A retrospective approach is commonly used in qualitative research, as it allows researchers to capture the meanings of past experiences that remain relevant to the present.

This approach facilitates the collection of rich and meaningful data through narrative and reflective techniques, including semi-structured interviews, learning documentation, and visual reflections in the form of students' drawings or illustrations. Visual representation is considered effective in revealing students' subjective understanding of environmental issues and ecological values, while also fostering emotional engagement through artistic expression (Heuver, 2023). The case study framework is particularly well-suited for understanding educational phenomena in a holistic and contextual manner.

The study involved three homeschooling students aged 12, 14, and 17, all of whom had participated in eco-literacy learning through the TBL model during the age range of 10 to 13. The research was conducted at Rumah Ulin, a learning environment that integrates ecological values and digital technology within family-based education.

The blended learning approach in this study combines technology-based online learning with hands-on field activities, enabling students to develop contextual and reflective understanding. A similar model was applied by Subastian et al., (2024), who found that project-based blended learning was effective in enhancing visual literacy and student engagement, particularly in the context of applied learning. This reinforces the relevance of the model employed in the present study.

Participants were selected using purposive sampling based on the following criteria, having reached the stage of formal operational cognitive development, which supports abstract and reflective thinking abilities (Piaget, 2009). Possessing at least two years of experience in using digital media for learning. Demonstrating interest and active participation in environmental activities and sustainable living practices.

Data collection was carried out in the home learning environments of each participant as well as through the online learning platforms used during educational interactions. Four main techniques were employed in the data collection process:

- Participatory observation, to capture students' engagement in digital learning activities and their interactions with ecological materials, as well as family facilitators.
- Semi-structured interviews with students and parents, aimed at exploring their perceptions, learning experiences, and reflections on the use of technology and the development of eco-literacy.
- Document analysis, including past learning records, digital learning activity archives (such as screenshots), and creative works related to environmental education.
- Students' visual reflections (in the form of drawings or illustrations), used to uncover their subjective understanding of ecological issues and their lived learning experiences.

Table 1 presents a summary of the profiles of participants involved in this study based on their age, TBL experience, and observed ecological activities.

Table 1. Participant Profiles

No.	Participant Code	Age at Interview (Years)	Age During TBL (Range)	Duration of TBL Experience (Years)	Observed Ecological Activities
1	P1	17	10–13	3	Making soap from used cooking oil, ecobricks, and eco-enzyme
2	P2	14	10–13	3	Video tutorials on soap-making, eco-enzyme, and waste sorting

No.	Participant Code	Age at Interview (Years)	Age During TBL (Range)	Duration of TBL Experience (Years)	Observed Ecological Activities
3	P3	12	10–12	2	Waste sorting, composting, caring for cats, and bringing a tumbler

The instruments used in this study included: an observation guide, focused on indicators of learning engagement, interaction with the environment, and ecological awareness behaviors, and an interview guide, developed based on the four main dimensions of eco-literacy: ecological awareness, environmental knowledge, ecological attitudes, and ecological actions.

The research instruments were designed following the eco-literacy framework, which encompasses ecological awareness, environmental knowledge, ecological attitudes, and ecological actions (Disinger & Roth, 1992; Hollweg et al., 2011). These four dimensions served as the foundation for both instrument development and data analysis to ensure consistency and alignment with the research objectives. Instrument validation was carried out through consultation with experts in ecological education and educational technology, ensuring relevance to the context and developmental characteristics of the participants.

Data were analyzed using a thematic analysis approach (Braun & Clarke, 2006). The process began with transcribing interview and observation results into text, followed by data reduction and coding through the identification of meaning units within participants' narratives. These codes were then grouped into four main thematic domains in line with the dimensions of eco-literacy. The next stage was theme interpretation, where the researcher constructed analytical narratives based on the interrelationships among the identified themes. To ensure the credibility and trustworthiness of the data, triangulation was conducted by comparing information from multiple sources, including interviews, observations, and documentation.

Thematic coding was carried out based on the four dimensions of eco-literacy described earlier. Each data unit was categorized according to these dimensions to construct a holistic thematic narrative, in line with approaches recommended in eco-literacy studies (Hollweg et al., 2011). The analysis process was conducted iteratively to capture the depth and complexity of students' eco-literacy development within the context of technology-integrated learning.

Table 2 presents a summary of the eco-literacy dimensions along with their thematic indicators and data sources used as the basis for analysis in this study.

Table 2. Eco-literacy Dimensions and Thematic Indicators

No.	Eco-literacy Dimensions	Thematic Indicators	Data Sources
1	Ecological Awareness	Recognizing environmental changes, asking critical questions, engaging in in-depth discussions.	Observation, Interview
2	Environmental Knowledge	Explaining recycling, the water cycle, and creating ecobricks.	Reflection, Documentation
3	Ecological Attitudes	Showing empathy toward animals, taking responsibility for leftover consumption.	Interview, Reflection
4	Ecological Actions	Sorting waste, making eco-enzyme, producing soap from used cooking oil, and natural bath soap.	Observation, Documentation

RESULTS

Results

Based on the thematic analysis, four main themes were identified in the development of eco-literacy: ecological awareness, environmental knowledge, ecological attitudes, and ecological actions. The frequency of these four themes across the entire dataset is visualized in Figure 1.

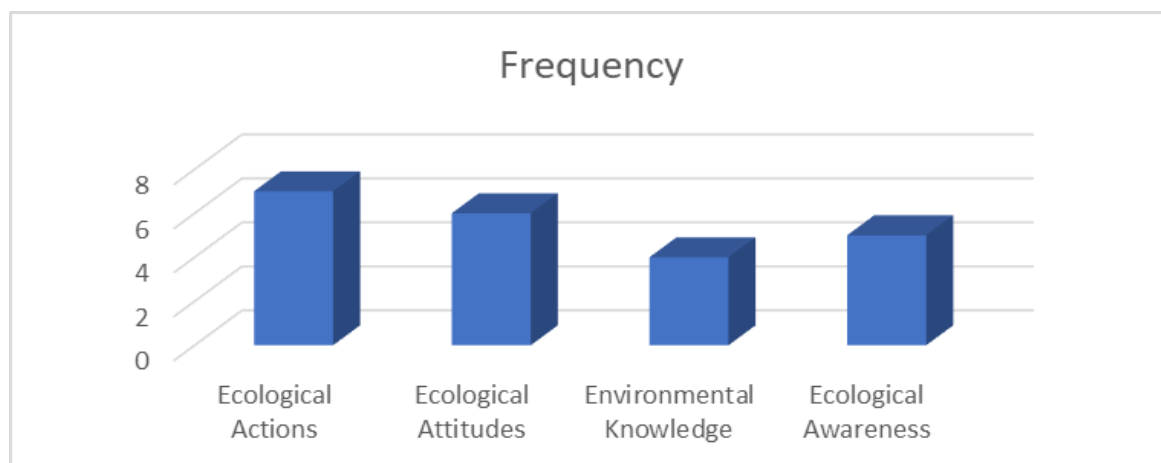


Figure 1. Frequency of Eco-literacy Themes Based on Thematic Coding

As shown in Figure 1, the most frequently emerging themes in the thematic coding are ecological actions and ecological attitudes. This finding indicates a strong behavioral and affective engagement of learners with environmentally friendly practices. The following discussion elaborates on the research findings based on the four established dimensions of eco-literacy.

Discussion

This study reveals that the implementation of the TBL model through blended learning, combined with constructivist and discovery learning approaches, effectively enhances eco-literacy among homeschooling students aged 10–13. The analysis was conducted based on four main themes representing the dimensions of eco-literacy: ecological awareness, environmental knowledge, ecological attitudes, and ecological actions. The findings indicate that ecological actions and ecological attitudes are the two most dominant dimensions, highlighting students' strong affective and behavioral engagement with environmental issues. The following section elaborates on the findings according to these four dimensions.

Ecological Awareness

Participatory observations and interviews revealed an increase in students' awareness of the environmental conditions around them. For example, students were able to identify the impacts of river pollution near their homes and relate them to everyday household activities. This awareness developed gradually through exposure to short documentary videos on YouTube showing the effects of domestic waste on river water color and aquatic life, further reinforced by digital simulations and reflections from direct field experiences. These findings align with constructivist perspectives, which emphasize the importance of authentic experiences in building new awareness (Bruner, 2001). Students began to understand that human actions carry tangible ecological consequences..

In addition to digital media, students were also encouraged to conduct direct exploration at a landfill site located about 8 km from their homes. This visit provided a concrete illustration of the impact of domestic waste accumulation on the environment. They observed towering piles of garbage, smelled the stench, and witnessed firsthand how the surrounding environment was affected. This activity became a powerful reflective moment, fostering students' emotional connection to waste management issues.

Furthermore, students demonstrated improved abilities in recognizing environmental changes and articulating ecological concerns in their own words. Orally, they began asking critical questions such as, "Why is the river water dirty and smelly?", "Why is the landfill full of garbage piles?", or "What happens to the trash we throw away?" all of which reflect the development of an inquiry-based ecological mindset.

Some students also reflected on their understanding orally through presentations they independently prepared using PowerPoint or illustrated (written) forms. These presentations not only reflected conceptual comprehension but also demonstrated their ability to organize environmental information logically and communicate ecological concerns to an audience. This activity served as an authentic space for ecological expression while fostering the confidence to speak about environmental issues based on personal observations and reflections.

The shift from passive observation to active questioning emerged as a key indicator of ecological awareness development at this age stage. The role of digital media and contextual exploration proved effective in strengthening students' ability to connect abstract concepts with real-life situations in their everyday lives.

Environmental Knowledge

Learning documentation and student reflections revealed a deepening understanding of environmental concepts, particularly those related to sustainable practices. Students were able to identify and explain various types of inorganic waste, such as paper, plastic, glass, and cans, as well as understand the basic principles of recycling. They also demonstrated knowledge of water conservation practices such as rainwater harvesting and were able to verbally describe different waste management techniques, including composting, the water cycle, ecobrick-making, and methods of household waste sorting.

To strengthen conceptual understanding through real-life experiences, students were taken to visit a waste bank managed by a local community under the supervision of the Department of Environment (DLH). During this visit, they directly learned about the processes of sorting, weighing, and reusing various types of inorganic waste. In addition, students gained insights into the economic value of recyclable materials and understood the role of institutions in supporting sustainable waste management systems at the community level.

In their family's daily routines, students also took part in recycling used cooking oil into environmentally friendly laundry soap and producing natural bath soap free from harmful chemicals. This learning process was not only hands-on but also enriched with digital learning through instructional videos from YouTube, which served as the main reference for systematically understanding the stages of soap-making. The children were not only participants but also became content creators; one of them was even assigned to produce a simple tutorial video on how to make laundry soap from used cooking oil as both a reflection activity and a contribution to digital environmental literacy.

In addition, students were also encouraged to utilize organic kitchen waste, such as fruit peels, to be processed into an eco-enzyme. This activity was carried out collaboratively as part of ecological experiments at home. Through the process, they learned about fermentation, decomposition time, and the benefits of eco-enzyme liquid for household cleanliness and small-scale organic farming. The activity fostered patience, accuracy, and provided direct understanding of ecological principles and circularity in organic waste management.

These various activities instilled the understanding that household waste does not always end up as garbage but can instead be transformed into useful products. Through this practice, students grasped the principles of reduce-reuse-recycle (3R) in an applied manner and were able to connect them with the concepts of water pollution and sustainable liquid waste management. Such activities served as an important bridge linking household practices with community-based environmental management systems, thereby expanding students' understanding from the micro to the macro context.

This learning process was built through a combination of independent exploration with the support of digital tools, reflective discussions with parents, and direct field experiences. These findings reinforce the view that technology can serve as an enhancer in conceptual learning when combined with reflection and contextual experiences (Laurillard, 2013). Other studies also emphasize the importance of integrating technology into community-based environmental literacy education (Baek et al., 2023). Their research shows that curricula combining eco-literacy and data literacy through technology-based community approaches can enhance students' understanding and active participation in local sustainability issues. This aligns with the findings of the present study,

where the use of digital tools such as videos, simulations, and online platforms also strengthened family engagement in the environmental learning process.

Furthermore, students demonstrated the ability to connect local environmental issues with broader ecological systems. For example, they were able to relate improper household waste disposal practices to declining river quality and its impact on aquatic biodiversity. The ability to synthesize knowledge across scales reflects the development of systemic thinking one of the key competencies in environmental education. The combination of digital learning and empirical experiences enabled students to internalize abstract ecological concepts into a personally meaningful and applicable understanding.

Ecological Attitudes

Semi-structured interviews revealed a shift in students' attitudes that reflected an increase in ecological affect. For instance, students expressed empathy toward displaced wildlife, including stray cats they encountered in daily life. In one case, a student felt compassion upon seeing a starving stray cat and asked their parents to adopt the animal. This response not only demonstrated emotional sensitivity toward living beings but also reflected a growing sense of ecological care rooted in direct interaction with both the social and natural environment.

In addition, students expressed feelings of guilt when littering. This awareness was reinforced through narrative-based video content and project-based learning activities that encouraged moral reflection on environmental issues. These findings highlight that contextual and emotionally grounded learning can foster ecological sensitivity from an early age. This aligns with the view that the affective domain is a crucial foundation in transformative ecological education (Vitaloka et al., 2022).

More than just an emotional response, students began to demonstrate a sense of responsibility in their everyday choices, such as reminding family members not to waste water or suggesting alternatives to the use of single-use plastics. These behavioral intentions reflect a maturing value orientation, where empathy is translated into responsible ecological awareness. The integration of narrative, reflection, and real-world problem-solving tasks enabled students to internalize environmental values not merely as conceptual knowledge but as guiding principles for their daily actions. This development underscores the importance of affective engagement in shaping ecological attitudes and fostering long-term ethical awareness.

Ecological Actions

Ecological actions represented the highest indicator of eco-literacy achievement. Documentation and observational data revealed that students consistently engaged in tangible pro-environmental behaviors. Within the daily routines of the Rumah Ulin homeschooling environment, the researcher's children established ecological habits as part of their household responsibilities. These included sorting waste by type, managing organic waste through composting, feeding pets (cats) as a form of care for living beings, and bringing their own food and drink containers (tumblers) when engaging in outdoor activities to reduce single-use waste.

In addition, the family regularly practiced sustainability at home, such as producing laundry soap from used cooking oil and natural bath soap free from harmful chemicals. These practices not only served to reduce household waste and dependence on industrial products but also functioned as direct learning opportunities for the children. They actively participated in the production process, developed an understanding of material reuse cycles, and internalized ecological values through practical, productive activities. This illustrates a concrete example of how ecological actions can be nurtured within the family as a transformative unit of ecological education.

These actions were not incidental activities but had become an integral part of the students' daily routines. Technology-supported learning reinforced these practices by providing impactful visualizations and a deeper understanding of the consequences of everyday behaviors. This finding aligns with studies showing that technology-based learning approaches can enhance students' active participation in pro-environmental actions, especially when combined with field experiences

(Zhao et al., 2021). That research emphasized the importance of integrating digital content with local contexts to foster sustainable ecological behavior.

This finding can also be viewed as an extension of previous studies highlighting the potential of digital media in introducing eco-literacy to young children in formal school settings (Ninsiana et al., 2022). In contrast, the present study demonstrates that a similar approach can be applied more flexibly within a non-formal, family-based learning environment (homeschooling), combining technology and authentic experiences reflectively and sustainably.

These findings reinforce the notion that TBL through blended learning can be effectively applied in non-formal education contexts. The integration of constructivist and discovery learning approaches facilitates the contextual and meaningful internalization of ecological values. This model successfully bridges the gap between digital learning and empirical environmental experiences. Such an approach is supported by recent meta-analyses showing that the integration of mobile devices in learning significantly enhances student performance, particularly when applied in experimental or problem-based exploratory tasks (Sung et al., 2022).

This study also contributes to the body of knowledge in environmental education by demonstrating that TBL, when integrated with blended learning as well as constructivist and discovery approaches, can effectively foster eco-literacy within non-formal learning environments. In contrast to the majority of eco-literacy studies that focus on formal school systems, this research provides empirical insights into how ecological awareness, knowledge, attitudes, and actions can be meaningfully developed within the context of homeschooling.

In addition, this study highlights the pedagogical value of the retrospective qualitative method in capturing long-term learning outcomes, while offering a new approach to evaluating the impact of early environmental education. This contribution carries practical implications for curriculum designers, educators, and policymakers seeking to promote sustainability education through alternative, technology-supported learning models.

The ecological actions carried out by the students not only influenced their family's lifestyle but also generated transformational effects on environmental attitudes and awareness. Active engagement in these practices reinforced a sense of responsibility toward sustainability, encouraged the formation of consistent ecological habits, and expanded the understanding that small household actions can make tangible contributions to the environment. For instance, successfully reducing organic waste, plastic waste, and used cooking oil in their household demonstrated a direct impact on the quality of their micro-environment, while also strengthening the students' confidence in contributing to ecological solutions.

The long-term effect of these habits is the formation of a sustainability-oriented mindset, embedded not only in learning contexts but also in everyday decision-making. Students no longer perceive environmental issues as knowledge detached from daily life but rather as an integral part of their identity and responsibility. This aligns with the goals of Education for Sustainable Development (ESD), which emphasize developing learners' capacity to make decisions and act reflectively, critically, and collaboratively in addressing sustainability challenges (Sanchez et al., 2025).

The limitation of this study lies in its scope, which only involved one homeschooling family, as well as the retrospective nature of the data collection. While this approach provided deep contextual insights, the findings must be generalized with caution. Future research is therefore recommended to involve more homeschooling communities with diverse social and geographical backgrounds. In addition, longitudinal studies on the long-term impact of technology-based learning on the enhancement of eco-literacy are needed to strengthen the validity of the findings and ensure the systemic sustainability of this learning model.

CONCLUSION

The results of this study indicate that the implementation of the TBL model through a blended learning approach, supported by constructivist and discovery learning strategies, is proven effective in enhancing the eco-literacy of homeschooling students aged 10–13 years. All four dimensions of eco-literacy ecological awareness, environmental knowledge, ecological attitudes,

and ecological actions—showed significant improvement, as evidenced by students’ engagement in reflective, exploratory, and sustainable practices within their households and local communities. The integration of learning technology with everyday life contexts plays a crucial role in fostering ecological understanding that is not only cognitive but also nurtures affective engagement and tangible behaviors supporting environmental sustainability.

Contextual, participatory, and experiential learning processes demonstrated high effectiveness in non-formal settings such as homeschooling, where learners have flexible and autonomous space to develop a meaningful understanding of ecological issues. These findings confirm that a holistically designed TBL model can bridge the gap between environmental education and digital pedagogy, which are often separated in conventional curricula.

The practical implications of this study emphasize the need to develop technology-based learning strategies that align with local wisdom and facilitate students’ active engagement in sustainability practices. Teachers, parents, homeschooling facilitators, and curriculum developers can utilize this model to design learning experiences that integrate digital literacy and ecological literacy in a balanced manner. This model can also be replicated by other homeschooling communities, non-formal educational institutions, and formal schools as an innovative approach to strengthening sustainability-oriented education.

The long-term impact of implementing this model is expected to cultivate a generation of learners with deep ecological awareness, critical thinking skills, and sustainable behaviors internalized in daily life. This has the potential to drive environmentally friendly cultural transformation at the family, community, and broader societal levels. Further research is recommended to explore the adaptation of this model in formal education contexts, communities with diverse socio-cultural backgrounds, and various age groups, in order to reinforce intergenerational eco-literacy through transformative and sustainable approaches.

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Development of application of self-help skills for children with intellectual disability in a wetland environment

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ABSTRACT

The limited ability to think in children with intellectual disabilities has an impact on their understanding of danger and personal safety. Children with intellectual disabilities need to be taught to recognize and help themselves from the dangers found in the surrounding environment. The purpose of this study was to develop an application of self-help skills for children with intellectual disabilities in a wetland environment. Using the Research and Development (R&D) method within the ADDIE model (Analysis, Design, Development, Implementation, Evaluation), the study was conducted at State Special Needs School 3 in Banjarmasin. Data were collected through tests, interviews, and documentation, and analyzed both qualitatively and quantitatively. The resulting application features four main menus: self-help during floods, fires, electrical short circuits, and encounters with wild animals. Each menu includes instructional videos outlining hazards and safety procedures. The application significantly improved participants' understanding, with post-test scores (1.480) surpassing pre-test results (1.130). Further research is recommended to evaluate the effectiveness of the application in fostering independence among children with intellectual disabilities.

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INTRODUCTION

Children with intellectual disabilities have below-average intelligence, which affects intellectual functioning and adaptive behavior. Intellectual function is related to the child's ability to learn, think, and solve problems. Adaptive behavior problems are related to the ability to adjust to circumstances in society and the surrounding environment (del Barrio, 2004). The limited ability to think makes it difficult for children with intellectual disabilities to adjust to their environment. Educational services must be provided according to the needs of children with intellectual disabilities, so that their potential can develop optimally and achieve independence (Raharjo & Sudarto, 2016). The ability to live independently is recognized as a marker of maturity; however, for children with intellectual disabilities, the difficulty in completing daily tasks indicates an inability in this area (Bridges et al., 2020).

The process of children's interaction with the environment, and the nearest learning resources (where they live) can provide insight and experience (Rachman et al., 2022). Characteristics of Banjarmasin, South Kalimantan are wetlands, so learning is developed by referring to the local wisdom environment of the South Kalimantan region (Prastitasari et al., 2022). Wetlands are areas

of swamp, brackish, peatland, and water; permanent or temporary; with stagnant or flowing water; fresh, brackish, or salty; including marine waters whose depth is not more than six meters at low tide. In the wetland environment, there are various living things, such as animals and plants, that live in the wetland environment (Harahap, 2016). Self-help needs are needed for children with intellectual disabilities to overcome various problems that are very likely to be faced in everyday life, including in interacting with their surroundings (Raharjo & Sudarto, 2016). Self-help skills involve various aspects, including disaster preparedness and personal safety skills, which are the ability to save oneself from danger (Hasyim et al., 2023). The ability of children with intellectual disabilities in self-help is specifically studied through a special program of self-care. Self-care is a skill that children with special needs must have or even master in order to take care of themselves in their daily lives so that they do not always depend on others (Kusnawan et al., 2022). Self-care also includes regular habits that a person engages in and personal safety (Anggraini & Marlina, 2018).

It is important to understand appropriate support related to self-help in children with intellectual disabilities (King et al., 2017) as it will determine effective strategies to implement (Mumpuniarti et al., 2023) according to the needs of children with intellectual disabilities, so that their potential can develop optimally and achieve independence (Raharjo & Sudarto, 2016). Mastery of self-development skills can help children adapt to their surroundings (Sulistyaningrum et al., 2021). In the context of unique wetland environments with distinctive ecologies, there are potential hazards, including encounters with wild animals, drowning in rivers, electric shocks, and fires (Campbell, 2019). Therefore, independence for children with intellectual disabilities should not only focus on daily living skills, but also on the ability to recognise risks and take safe preventive measures (Downs et al., 2024). Intervention programmes need to internalise wetland-based safety education, which includes training in recognising dangerous zones and safety principles in wetland environments.

Various domains in the self-help program can be taught to children with intellectual disabilities, one of which is self-help skills. Self-help is the ability to overcome various problems in daily life, such as avoiding and controlling oneself from the dangers of water, fire, electricity, pets, and wild animals (Damastuti, 2023) and overcome various other problems that are very likely to be faced in everyday life, including in interacting with the surrounding environment (Raharjo & Sudarto, 2016). This is because one of the practical skills that children with intellectual disabilities find difficult to master is self-help (Damastuti, 2020). Life skills for children with intellectual disabilities can be taught by applying appropriate teaching strategies such as task analysis, instruction, and the use of assistive technology (Bouck et al., 2025). Assistive technology is an effective tool for individuals with intellectual disabilities to master daily living skills and reduce their dependence on others (Stierle et al., 2023). Assistive technology can be used to create support systems that enable children to master various daily living skills (self-help skills) (Lancioni et al., 2024).

Several studies are relevant to this research. First, Stierle et al., (2023) studied the use of task-based smartphone technology using cooking instruction videos on three adults with intellectual disabilities, which improved their daily living skills by 99%–100%. Second, Kang & Chang (2020) studied how the use of augmented reality games can improve skills in using ATMs in three students with intellectual disabilities. Unlike previous studies that focused on daily living skills, this study developed an application to train self-safety skills that are crucial for children with intellectual disabilities living in unique and challenging wetland areas. The advantage of this application is that it contains videos on how to safely access the wetland environment, including self-awareness and rescue related to the dangers of flooding, fire, electricity, and wild animals. In addition, the application is practical to carry anywhere, and the videos can be played repeatedly by children with intellectual disabilities, which is in line with the learning characteristics of children with intellectual disabilities, in order to increase awareness when accessing or interacting in swamp environments. Thus, this study aims to support the self-help skills of children with intellectual disabilities in wetland environments through the use of smartphone applications.

METHOD

The method used in this research is Research and Development (R&D), which is a method that aims to develop a new product or improve existing products (Barokati & Annas, 2013). The research implementation model is ADDIE, which is a systematic learning design model, developed or arranged programmatically with a systematic sequence of activities in an effort to solve learning problems related to learning resources that are in accordance with the needs and characteristics of students. The ADDIE model can be used for a variety of models, learning strategies, media, and teaching materials.

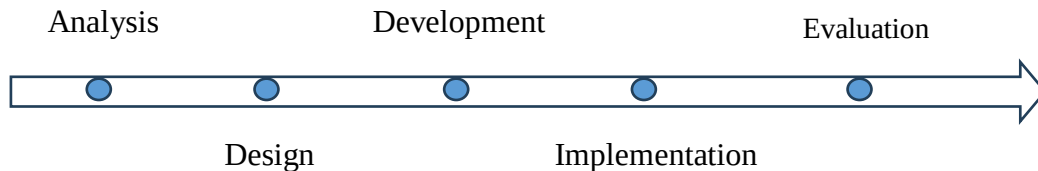


Figure 1. Research Stages

The analysis process was carried out through a preliminary study to determine the understanding of students with intellectual disabilities regarding self-help skills. The design process aimed to design a self-help skill development application for children with intellectual disabilities in a wetland environment based on the analysis results obtained. Development activities are conducted to create applications that have been designed. The implementation process is carried out by conducting application trials and directly involving students with intellectual disabilities to use the application. The subjects in this study consisted of two groups: students and teachers. Twenty junior and senior high school students with intellectual disabilities acted as application users, while the second group consisted of 16 teachers who were involved in assessing the application's practicality. Subjects were selected using purposive sampling with the following criteria: students known to have intellectual disabilities and actively attending Special Needs School 3 Banjarmasin at the junior and senior high school levels. The selection criteria for teachers included having experience teaching students with intellectual disabilities. The last stage, evaluation, aims to improve the results of the trial so that the application becomes feasible and can facilitate the needs of self-help skills for children with intellectual disabilities.

Table 1. Overview of Research Instruments

No.	Type	Objective	Data source	Usage stage	Form	Instrument
1	Pre-test & Post-test	To measure the level of understanding at the beginning and after implementation of the application for students with intellectual disabilities regarding self-help skills in wetland environments. The focus of the pre-test and post-test instruments was to determine knowledge about the dangers and how to save oneself from floods, fires,	Students with intellectual disabilities	Analysis and evaluation	Multiple choice	• What would you do if there were a flood near your house? • Why shouldn't we play in the water during a flood? • What should you do if there were a fire inside your house? • Why should we leave the house immediately during a fire?

No.	Type	Objective	Data source	Usage stage	Form	Instrument
		electrical short circuits, and the dangers of wild animals.				• What should you do if you find a stripped electrical cable? • How can you safely use electrical appliances? • What should you do if you see a snake in the swamp? • Why are scorpions considered dangerous? • Why are crocodiles considered very dangerous to humans? • What should you do if you find a centipede inside your house?
2	Application Practicality Questionnaire	Measures the practicality of the application from a teacher's perspective. Indicators include application appearance, installation, ease of use, language clarity, text readability, and video appeal and clarity.	Special Needs School Teacher	Evaluation	Question naire	• Is the SINORI app's interface attractive? • The menus in the SINORI app are easy to understand • Is the text displayed in the SINORI app easy to read? • Can the SINORI app be easily installed on your Android smartphone? • Can the SINORI app be accessed smoothly? • Is the language in the SINORI

No.	Type	Objective	Data source	Usage stage	Form	Instrument
						app clear? • Do the videos in the SINORI app play smoothly? • The videos in the app are engaging and easy to understand? • The SINORI app can help you develop self-help skills in wetland environments . • Teaching self-help skills in wetland environments is more practical and easier using the SINORI app?

Quantitative data from the pre-test and post-test results were analyzed by comparing the differences in scores, average values, highest scores, and lowest scores between before and after using the application to see the improvement in the understanding of students with intellectual disabilities. Data from the practicality questionnaire filled out by the teacher were analyzed descriptively to conclude the level of practicality of the application.

RESULTS

Results

Analysis

A needs analysis of self-help applications in a wetland environment was conducted by asking children with intellectual disabilities to complete a self-help pre-test. The results obtained are as follows:

Table 2. Pre-Test Results

No.	Initial Name	Score Pre-Test
1	MW	60
2	M	70
3	A	60
4	Z	50
5	RT	60
6	EM	50
7	DSP	50
8	PN	50

No.	Initial Name	Score Pre-Test
9	MN	60
10	SPPH	30
11	R	70
12	J	70
13	B	70
14	SS	40
15	P	40
16	KA	50
17	Y	60
18	MHR	70
19	YY	50
20	SRS	40

Based on the results above, it is known that not all respondents have knowledge and understanding of how to help themselves. This is evidenced by the diverse pre-test scores, the lowest score is 30, and the highest score is 100, which can be achieved by two children with intellectual disabilities. This analysis is the basis for teaching self-help skills in wetland environments so that children with intellectual disabilities are able to recognize and help themselves when dealing with hazards in wetland environments.

Design

Following the pre-test results of self-help skills in children with intellectual disabilities, the research team conducted a focus group discussion to discuss the application design. There were 20 participants in the focus group discussion, consisting of students, special education teachers, and therapists for children with special needs.



Figure 2. Focus Group Discussion

The discussion resulted in the design and appearance of the self-help application with the following description:



Figure 3. Design Self-Help Application

Development

The design of the application is shown to experts to be developed into an application that can be used practically by potential users. The results of expert development resulted in different changes to the logo, menu display, and sub-menu display. The results of the application developed by the expert are as follows:

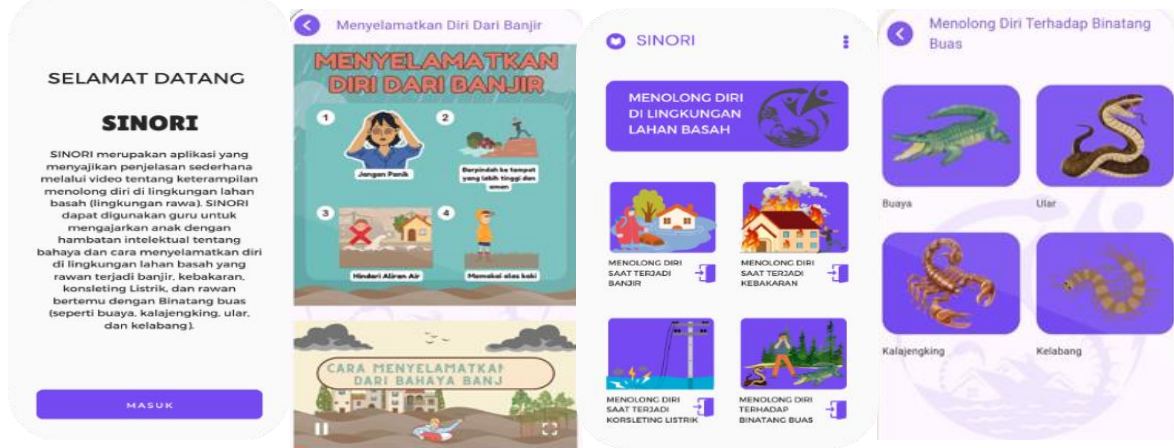


Figure 4. Display Menu

Implementation

After the application was developed by experts (teachers and therapists of Children with Special Needs) through Focus Group Discussions, the research team conducted an application trial at Special Needs School 3 Banjarmasin by inviting sixteen teachers at the junior and senior high school levels and twenty children with intellectual disabilities at the junior and senior high school levels who had filled in the pre-test questions at the previous stage. Implementation was carried out by socializing and testing the application to determine the practicality of the application and the understanding of children with intellectual disabilities as application users.



Figure 5. Test out Self-Help Apps

Evaluation

The last step was to evaluate by giving a post-test to twenty children with intellectual disabilities and asking teachers to fill out a questionnaire on the practicality of the application. The results of the post-test and the questionnaire are as follows:

Table 3. Comparison of Pre-Test and Post-Test Results

No.	Initial Name	Score Pre-Test	Score Post-Test
1	MW	60	80
2	M	70	90
3	A	60	90
4	WITH	50	50

No.	Initial Name	Score Pre-Test	Score Post-Test
5	RT	60	100
6	IN	50	50
7	DSP	50	80
8	PN	50	50
9	MN	60	70
10	SPPH	60	30
11	R	70	90
12	J	70	90
13	B	70	90
14	SS	40	80
15	P	40	50
16	THE	50	70
17	AND	60	80
18	MHR	70	100
19	YY	50	50
20	SRS	40	90
Total		1130	1480
Average		56.5	74
Highest		70	100
Lowest Score		40	50

Based on the table above, it can be seen that children with disabilities showed an increase in scores after the post-test was conducted. This is evidenced by the difference in total score, average, highest score, and lowest score, which are higher than the pre-test results. The application practicality questionnaire was distributed to 16 teachers during socialization activities and application trials. Socialization activities and application trials, the appearance of the application is attractive, the menu display in the application is easy to understand, the application can be easily installed on your Android smartphone, the clarity of the language in the application, the videos in the application are interesting and easy to understand and the application can help you improve your self-help skills in a wetland environment.

Discussion

South Kalimantan is a province with wetland areas. Wetlands are important for human life, including providing drinking water sources, habitat for various living things, controlling floods, erosion, pollution, global climate control, and others (Harahap, 2016). Wetland characteristics influence the social life and interaction of communities in South Kalimantan with the environment. Wetlands also support the lives of various animals, including wildlife such as snakes and crocodiles.

Some areas in wetland settlements are prone to flooding (Annisa et al., 2021). Flooding generally occurs in various locations in South Kalimantan almost every year (Sompa et al., 2021). A catastrophic event other than flooding that can occur in wetland areas is fire (Kamlun & Phua, 2024). Fires can be caused by various natural factors, such as lightning, and human factors due to negligence, including imperfect electrical installations and the use of unsafe electrical equipment.

People who live in wetland environments must be prepared for various types of disasters (Deasy et al., 2023). Preparedness is part of efforts to help and protect oneself and the surrounding environment because it has an important role and influences community actions when disasters occur. Disaster is a problem that results in ecological losses, casualties, damage to facilities and infrastructure caused by natural and unnatural factors, resulting in damage to buildings and loss of property (Ilmi et al., 2022). The existence of disasters poses a threat and disrupts social life for disaster victims. Preparedness can be done if a person knows a disaster (Mas'Ula et al., 2019). Knowledge and attitudes are the first indicators to measure community disaster preparedness.

Children with intellectual disabilities have low knowledge and self-help/preparedness skills (Kwon, 2009). Children with intellectual disabilities show a lack of preparedness when a disaster occurs, do not understand the importance of protecting themselves when indoors and outdoors, do not understand how to use safety equipment to help themselves, and do not understand the

importance of self-help skills (Yutikasari & Azizah, 2019). Most respondents demonstrated a lack of understanding in terms of independence. Of the 20 respondents, fifteen children with intellectual disabilities scored below 70, three children scored 70, and two children scored 100. The lowest pre-test score was 30, obtained by a child with an intellectual disability at the secondary school level. Independence in children with low intellectual disabilities is caused by low intelligence levels, resulting in children with intellectual disabilities lacking understanding and being unable to perform actions that can help themselves. Children with intellectual disabilities will depend on others, especially their parents, because they face challenges in terms of independence (Kusnawan et al., 2022). Ideally, children at the junior high and high school levels should be able to recognise various dangers and help themselves, such as floods, fires, wild animal hazards, and electrical short circuits.

Designing devices for children with intellectual disabilities is not easy due to the nature of the disability; designers of technology for children with intellectual disabilities should focus on the capabilities that enable the use of the device, not on the disability. The design of the self-help application also adapts the characteristics of the South Kalimantan wetlands and the possibility of disasters that can occur in the surrounding environment, so that there are four scopes of self-help presented in the application, namely the dangers of water, fire, electricity, pets, and wild animals. Therefore, at the design stage, there were 20 focus group discussion participants consisting of students, special education teachers, and therapists for children with special needs, discussing the design of self-help applications for children with intellectual disabilities.

Children with intellectual disabilities need to be prepared to have independence and be able to carry out daily life without the help of others, so it is necessary to learn about taking care of yourself, which is easily accepted and at the same time interesting (Eltantawy, 2023). Self-help is the ability to maintain safety and overcome danger. The ability of children with intellectual disabilities to recognize and help themselves from danger is obtained through a special program at school and is known as the Special Self-Build Program (Meesupmun et al., 2022). The existence of a special self-help program indicates that children with intellectual disabilities need teaching to improve their self-help skills. Learning for children with intellectual disabilities, such as self-help, must use concrete media or utilize modern technology in the form of applications on mobile phones (Sarcco et al., 2023). There are many children with special needs who have cellphones and use them in their daily activities; therefore, the design stage aims to design self-help applications that can be used every day to increase understanding of hazards/disasters and alertness in the event of a disaster in children with intellectual disabilities (Isrona et al., 2021). Designing self-help applications for children with intellectual disabilities can support self-help learning at school and at home. The results of the design stage are the design of the logo, the appearance of the main menu, the appearance of the contents of each sub menu, and the background of each application page.

At the development stage, the research team met with experts to realize the design that had been discussed during the focus group discussion. There are several changes agreed with the expert, namely the application logo that represents the contents of the menu, the application page background, the initial appearance, the menu display, the sub menu display, and the contents of each sub menu presented in the form of animated images and videos. The utilization of assistive technology for children with intellectual disabilities can increase functional independence, self-determined decision making, employment, educational opportunities, and others (Boot et al., 2017; Dekelver et al., 2015). The use of videos in self-help applications is tailored to the characteristics of children, combining audio, visual, motion, color, and three-dimensional elements as learning media is very appropriate in learning. Therefore, video media instruction is a widely used medium because video combines well the elements needed in self-help instruction, such as audio, visual, motion, color, and three-dimensional impression, so that it can attract the attention of children with intellectual barriers to learning are expected to focus on paying attention when the video is played (Aziz & Murtadlo, 2018).

At the implementation stage, socialization to teachers and children with intellectual disabilities is carried out first before children with intellectual disabilities try the application independently on their respective mobile phones. Self-help applications do not have many pages,

small application sizes, can be used offline, the content on each application page is not too much, and information videos with a short duration and using uncomplicated sentences can make it easier for children with intellectual disabilities to use the application independently. The last stage is evaluation to determine the understanding of children with intellectual disabilities through post-tests and filling out application practicality questionnaires filled out by teachers.

Individuals with intellectual disabilities are vulnerable to injury; they should be aware of potential hazards and develop skills to protect themselves from possible injury (Park, 2022). Based on the post-test results, the app development objective can be achieved as children with intellectual disabilities showed better understanding and post-test scores. The comparison between the overall pre-test and post-test scores was 1.160 and 1.510. The increased score of children with intellectual disabilities in the post-test shows that audio-visual media is very good at explaining a process and can explain a skill (Nurhuda et al., 2024). The lowest score in the pre-test was 30, while the lowest score in the post-test was 50. The existence of SINORI as a learning medium is also expected to increase the preparedness of children with intellectual disabilities to protect and help themselves.

The assessment of the practicality of the application was agreed by 16 teachers on several statement items, namely, the menu display in the SINORI application is easy to understand, the text displayed in the SINORI application is easy to read, and the video in the application is interesting and easy to understand. SINORI application as a learning media is a tool that can help the teaching and learning process and serves to clarify the meaning of the message conveyed, so that it can achieve learning objectives better and perfectly (Riyadi et al., 2020). Applications as learning media have the advantages of being practical, easy to use, and can be accessed anywhere. Another advantage of application-based learning media is that it facilitates learning because it can be used repeatedly and used in various places (Fitriyani et al., 2023). The convenience of smartphones has proven to open up new opportunities for children with special needs in adapting to society.

CONCLUSION

The development of the "SINORI" application, designed using the ADDIE model, has proven effective in improving the understanding and self-help skills of children with intellectual disabilities in wetland environments. This success is demonstrated not only by the significant increase in the total score from 1.130 in the pre-test to 1.480 in the post-test, but also by the practicality assessment by teachers, who found the application easy to use, engaging, and relevant to students' needs. This application successfully addresses the challenges of contextual learning by presenting visual materials in the form of videos about self-rescue from wetland-specific hazards, such as floods, fires, electrical short circuits, and wild animals.

As an educational technology innovation, SINORI makes a practical contribution by providing learning media that can be accessed repeatedly by children with intellectual disabilities. This application has the potential to foster children's independence and preparedness in facing potential risks in their surroundings, thereby minimizing dependence on others.

For future development, several further studies are recommended. First, a longitudinal study is needed to evaluate the long-term effectiveness of application use on persistent changes in independent behavior in real-life situations. Second, future research could explore adding interactive features such as gamification or simulations to enhance user engagement and knowledge retention. Third, it is recommended to adapt and test this application in other geographic contexts with different potential disasters (e.g., earthquakes or tsunamis) or in other populations of children with special needs.

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Problem-based learning enhanced by electronic textbooks: The effects on students' critical thinking abilities

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ABSTRACT

Students' critical thinking skills remain relatively low due to learning activities that are still dominated by teacher-centered approaches and the limited use of interactive learning media. This condition makes students less engaged in analyzing, reasoning, and solving problems in a deep and meaningful way. To overcome this issue, the problem-based learning model assisted by electronic textbooks was applied to promote independent, active, and contextual learning. This study aimed to investigate the impact of the PBL model, supported by electronic textbooks, on students' critical thinking skills. The research employed a quasi-experimental design with a population of 270 students, from which 60 were selected using the cluster random sampling technique. The instrument used was a critical thinking test administered during the pretest and posttest. The data were analyzed using a parametric statistical test, specifically the independent sample t-test. The results showed that the t-value (2.656) was greater than the t-table value (1.671), indicating a significant effect of PBL assisted by electronic textbooks on students' critical thinking skills. Future research is recommended to explore other innovative learning models, integrate additional learning variables, and apply these models to larger and more diverse samples across various educational levels to obtain more comprehensive and generalizable results.



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INTRODUCTION

The digital era has brought about substantial transformations in the domain of education as a consequence of the advancement in the realm of technological innovation and science. These changes include the necessity regarding the twenty-first-century competencies, which prioritize critical, creative, communicative, and collaborative thinking. Critical thinking is one of the most critical intellectual abilities possessed by students must acquire. This capacity serves as the foundation for the rational and reflective evaluation of information, problem-solving, and the decision-making process (Khusna et al., 2024; Pitorini et al., 2024; Yeh et al., 2023). In line with what Yeh et al., (2023) said, critical thinking abilities are essential competencies that students must develop to analyze problems, evaluate information logically, and generate suitable solutions.



In an academic environment, critical thinking skills are the foundation for a meaningful learning process (Nurfathurrahmah, 2018; Widayati & Khofifah, 2022). Students who think critically are not only able to understand the material conceptually but can also relate it to real contexts, formulate in-depth questions, and provide logical and argumentative solutions to a problem (Anggela et al., 2021; Aslan & Aybek, 2024). Another definition of critical thinking is the ability to reason logically, with an emphasis on making judgments regarding truth and determining appropriate courses of action (Leny et al., 2024).

Cognitive learning achievement plays a crucial role in the education system, as the core of learning activities involves developing thinking and memory skills. Critical thinking ability is a fundamental skill that students must possess. Through critical thinking, students can think logically and make appropriate decisions and choices based on the data they obtain (Sudiarti et al., 2023). Therefore, these skills are very important in compiling scientific assignments, class discussions, and completing case studies that require high-level reasoning.

In spite of the fact that abilities in critical thinking are indispensable for students, the field's reality is that numerous students continue to confront a myriad of challenges as they strive to foster these abilities. One of the primary issues is the limited capacity of students to conduct in-depth analyses of information. Many students have a tendency to accept information in its current state without engaging in a process of critical reflection, clarification, or evaluation of the content and sources of the information. Another problem is the weak ability of students to formulate logical and systematic arguments. In discussions or academic writing, students often have difficulty formulating opinions that are supported by strong reasons, relevant data, and coherent reasoning structures. This shows that they are not yet accustomed to using logic and high-level thinking in processing and conveying ideas.

The learning approach, which remains focused on memorization and mastery of material, is another factor contributing to students' low critical thinking abilities. The teacher-centered learning model tends to limit students' active roles in exploring, questioning, and solving problems independently (Fahrudin et al., 2025; Susanto & Hapudin, 2024). As a result, students do not get enough opportunities to hone their critical thinking skills in a challenging and meaningful learning context. These problems indicate the need for transformation in learning strategies in higher education. Learners are required to be positioned as active participants in the learning process, actively engaged in the resolution of real-world issues, able to think reflectively, and supported by technology-based and contextual learning resources.

Learning based on problems constitutes one of the learning models that can enhance students' critical thinking abilities. A learning model that emphasizes the importance of problems as the primary stimulus for learning is known as problem-based learning (Aziz et al., 2016; Misidawati & Sundari, 2021; Nurfathurrahmah, 2018). Through PBL, students are encouraged to learn independently and collaboratively in analyzing real problems, formulating solutions, and reflecting on the thinking process that has been gone through (Chaidam & Poonputta, 2022; Ernawati et al., 2023). In accordance with this, one of the learning methods that is considered effective in the development of critical thinking abilities is problem-based learning. This model emphasizes the use of real-world problems as the foundation for learning (Kloeg, 2023; Orhan, 2024). The presentation of problems in the Problem-Based Learning model employs real-world issues as materials for discussion during the learning process. These problems are solved by students, with the expectation that they will develop the habit of thinking critically when addressing issues based on real-life contexts (Yhonara et al., 2022). Therefore, PBL encourages students to explore knowledge, formulate hypotheses, collect data, and develop solutions to the problems faced.

According to Arends Üce & Ateş (2016), Waalkes et al., (2024) and Zeng & Ruannakarn (2023), the formal structure of the problem-based learning model typically comprises five primary steps, namely: 1) problem orientation, the lecturer presents a complex and authentic contextual problem to stimulate curiosity and build students' curiosity; 2) organize students to learn, students are grouped and directed to understand the problem, identify what is already known and what needs to be known, and plan problem-solving strategies; 3) guide individual and group investigation, students explore information, discuss, experiment, or review literature to collect relevant data; 4)

develop and present the work, students process the results of the investigation, draw conclusions, and present solutions or products to other groups; 5) examination and evaluation of the problem-solving process, as lecturers and students collaboratively reflect on the learning experience, evaluate the resultant solutions, and appraise the efficacy of teamwork and individual contributions.

The success of PBL implementation is highly dependent on the media and learning resources used. In the contemporary digital age, the utilization of electronic textbooks is a strategic decision to facilitate problem-based learning (Muga et al., 2017). Electronic textbooks can serve as an alternative learning resource to replace printed textbooks that do not adequately support student participation. This aligns with Reinita & Putri (2024), who stated that learning resources, such as printed textbooks, have not been effective in enhancing student participation and engagement during the classroom learning process. Electronic textbooks offer succinct and interactive content, enhanced by multimedia links, quizzes, and navigational tools that facilitate independent comprehension and exploration of concepts for students (Aulia et al., 2023; Riwu et al., 2018). In line with what Setyowati & Satrio (2025) said that electronic textbooks as digital learning resources that are designed systematically and pedagogically have great potential in supporting the development of students' critical thinking. Moreover, electronic textbooks not only convey information in textual format but also incorporate diverse multimedia components, including images, videos, interactive simulations, and reflective quizzes (Chen et al., 2024; Riwu et al., 2018). These elements encourage students to engage with the material actively, rather than merely absorbing information passively, by evaluating, analyzing, and interpreting it.

Based on a review of relevant studies, the novelty of this research lies in the integration of the Problem-Based Learning model with electronic textbooks as interactive and contextual learning support media. This innovation offers a learning experience that encourages students to solve problems and actively develop their critical thinking skills. Unlike previous studies that generally examined the effectiveness of PBL in conventional settings, this research introduces a digital approach that aligns with current educational demands. Furthermore, the focus on prospective teachers offers a new contribution to efforts aimed at improving the quality of future educators who are critical, creative, and adaptable to developments in educational technology.

The use of electronic textbooks at the student level will increase student independence in learning anytime and anywhere because it is easier to access. This is in line with what experts have said: electronic textbooks can be accessed anytime and anywhere through various digital devices such as laptops, tablets, or smartphones. Students are able to study independently and customize their study time to suit their individual requirements (Jazuli et al., 2018). The integration of electronic textbooks into the structure of problem-based learning is anticipated to enhance cognitive engagement and deliver a more impactful learning environment for students.

According to the description, it is crucial to empirically investigate the effect of the problem-based learning model, which is facilitated by electronic textbooks, on the critical thinking abilities of students. Consequently, the objective of this investigation is to ascertain the extent to which the critical thinking abilities of students are impacted by the problem-based learning model, which is facilitated by electronic textbooks.

This research contributes to the development of learning innovation in higher education by implementing the Problem-Based Learning model, supported by electronic textbooks. The findings of this study are expected to help students think more critically and independently in solving problems. Practically, this research can serve as an example for other educators in designing more engaging learning processes that align with technological advancements. Furthermore, this study enhances the use of electronic textbooks as a learning medium that supports the development of students' higher-order thinking skills.

METHOD

The current research is quantitative by design and applies a quasi-experimental methodology. The objective of quasi-experimental analysis is to ascertain the effect of an implementation. On the subject of the study (Sugiyono, 2010). In this investigation, a pretest-posttest control group design was implemented. The research design is concisely summarized in the following scheme:

Table 1. Control Group Design Schematic for Pretest-Posttest

No.	Group	Pre-test	Treatment	Post-test
1	Experimental Class	O ₁	X	O ₂
2	Control Class	O ₃	-	O ₄

In the experimental class, a pretest (O1) was administered prior to the treatment, followed by the experimental treatment (X) in which students used electronic textbooks to participate in problem-based learning. Finally, students were administered a posttest (O2) following the treatment. This information is derived from the aforementioned research design. Furthermore, the control class was administered a pretest (O3) and posttest (O4) without any treatment, utilizing electronic textbooks and PBL learning.

The study population comprised 270 candidates for elementary school teaching in their sixth semester. Samples were randomly selected from the entire population utilizing the cluster random sampling method, resulting in two classes comprising a total of 60 students, with 30 students designated as the experimental group and 30 as the control group. The experimental group receives a learning intervention utilizing a problem-based learning model supplemented by electronic textbooks. The control group is one that does not receive any special treatment, engaging solely in standard learning through direct instruction.

The research instrument employed was an assessment of students' critical thinking abilities. The assessment employed a multiple-choice format comprising 20 questions, each valued at 5 points. The assessment was administered to students on two occasions: a pretest and a posttest. The pretest assessed students' initial abilities, while the posttest evaluated the outcomes the capacity for critical thinking among students following experimental treatment with a problem-based learning model supported by electronic textbooks. The grid for the students' critical thinking ability test can be seen in the following Table 2.

Table 2. Student Critical Thinking Ability Test Grid

No.	Aspect of Critical Thinking Ability	Indicators	Expected Behavior Description	Number of questions
1	Interpretation	a. Identifying problems presented in the learning context. b. Understanding the meaning of relevant concepts, terms, or data.	Students are able to explain the meaning of a concept or problem and recognize important related information.	3
2	Analysis	a. Describing relationships among concepts, ideas, or data. b. Distinguishing between facts and opinions in a statement.	Students are able to identify the structure of arguments, distinguish relevant from irrelevant information, and examine cause-and-effect relationships within a phenomenon.	4
3	Evaluation	a. Assessing the accuracy and relevance of information. b. Evaluating the logic of arguments and evidence used to support conclusions.	Students are able to judge the validity of information, weigh the strength of arguments, and determine the reliability of data sources.	3
4	Inference	a. Making assumptions or predictions based on available evidence and data. b. Formulating alternative solutions to given problems.	Students are able to draw logical conclusions from existing information and develop reasonable possible solutions.	4

No.	Aspect of Critical Thinking Ability	Indicators	Expected Behavior Description	Number of questions
5	Explanation	a. Providing logical reasons to support decisions or answers. b. Presenting the results of analysis or solutions with coherent arguments.	Students are able to explain their reasoning process rationally and support it with strong evidence.	3
6	Conclusion	a. Drawing objective conclusions based on the analyzed data. b. Reassessing conclusions to ensure consistency and accuracy.	Students are able to derive conclusions supported by evidence and sound logic while reflecting on the accuracy of their reasoning.	3

The collected data on the critical thinking abilities of learners were analyzed to reach a conclusion. The data underwent analysis through prerequisite tests, specifically the normality test and the homogeneity test. The criteria for decision-making regarding the normality test were based on significance. According to the definition, A dataset is considered to be normally distributed when the significance value exceeds 0.05. Additionally, hypothesis testing was done using an independent sample t-test. If the t-count is higher than the value shown in the t-table, the null hypothesis should be thrown out according to the rules for conducting hypothesis testing. Majority support for H_a suggests a big difference in the average level of critical thinking between the experimental and control groups. To show that there isn't a significant difference in the average critical thinking skills between the experimental and control groups, the t-count must be less than the t-table threshold. This means that the null hypothesis must be accepted and the alternative hypothesis must be rejected. Researchers used a normalized Gain test to look at how problem-based learning with electronic textbooks affected students' ability to think critically. The normalized Gain value was subsequently classified into three distinct categories: high, medium, and low, as illustrated in Table 3 below.

Table 3. Normalized Gain Score Criteria

No.	Criteria	Normalized Score
1	High	$\text{Gain} \geq 0.7$
2	Medium	$0.7 > \text{Gain} \geq 0.3$
3	Low	$\text{Gain} < 0.3$

The Normalized Gain score is classified as high if it exceeds 0.7, medium if it is between 0.3 and 0.7, and low if it is less than 0.3, as shown in the table above. The procedures employed in this investigation are as follows: 1) defining the problem and establishing research objectives; 2) analyzing theories related to problem-based learning, electronic textbooks, and critical thinking skills; and formulating hypotheses. 4) ascertaining the employed research design; 5) identifying the population and sample of the study; 6) developing a tool to assess students' critical thinking abilities; 7) testing the control and experimental groups' critical thinking skills beforehand; 8) treatment group with a combination of problem-based learning and electronic textbooks, and a control group that only received traditional lectures and class discussions; 9) administering a posttest to both groups to evaluate critical thinking skills following the intervention; 10) acquiring and analyzing data through statistical methods; 11) reviewing the data to ascertain whether the two groups (experimental and control) differ significantly; 12) analyzing results in relation to established theories and prior research; 13) briefly outlining the study's conclusions.

RESULTS AND DISCUSSION

Results

The analysis utilized test results, particularly pretest and posttest scores from both the experimental and control classes, to assess the critical thinking abilities of prospective elementary school teachers. The students in the control group received more traditional forms of direct

instruction and discussion, whereas those in the experimental group used an online textbook to supplement a problem-based learning approach. Figure 1 presents the average scores from pre-tests and post-tests for the control and experimental classes.

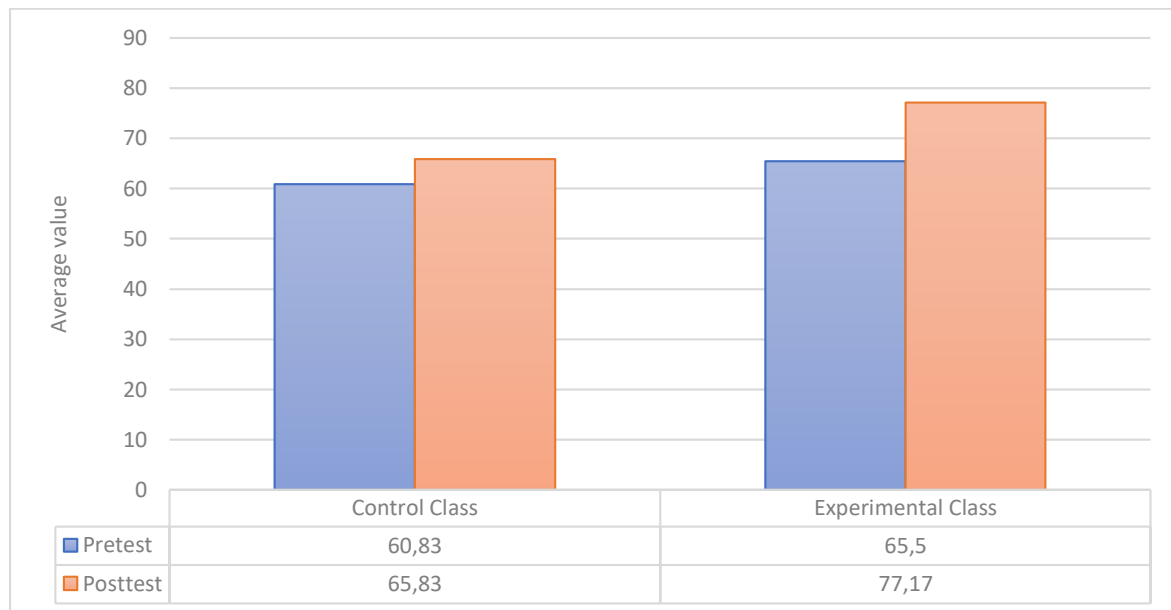


Figure 1. Analysis of Average Pre-test and Post-test Values between Experimental and Control Groups

Figure 1 illustrates that the mean posttest score surpasses the mean pretest score for both the experimental and control groups. The experimental group demonstrated a greater enhancement in students' critical thinking skills compared to the control group.

A hypothesis test was performed to evaluate the impact of the problem-based learning model, implemented with electronic textbooks, on students' critical thinking abilities. The initial step was to administer a prerequisite test that included a homogeneity and normality test. The SPSS software was employed to analyze the normality and homogeneity tests. The data on critical thinking skills of prospective elementary school teachers underwent tests for normality and homogeneity. The outcomes are as follows.

Table 4. Importance of Homogeneity and Normality Assessments

No.	Class/Group	Sig. Normality (Kolmogorov-Smirnov)		Sig. Homogeneity (Levene Statistic)
		Pretest	Posttest	
1	Experiments	0.235	0.142	0.891
2	Controls	0.536	0.432	

Table 4 reveals that the pretest exhibits a significance value of 0.235 in the experimental class, whereas the posttest shows a significance value of 0.142. The significance value for both the pre-test and post-test in the experimental class exceeds 0.05, indicating that the data in this class adheres to a normal distribution. The control class shows a pretest significance of 0.536 and a posttest significance of 0.432. The value is greater than 0.05, suggesting that the control class data adheres to a normal distribution. The Levene statistic test produced a significance value of 0.891, which is above the 0.05 threshold. This suggests that both the experimental and control classes demonstrate identical data variance, indicating a homogeneity in the data.

The outcomes of the normality and homogeneity assessments were employed to perform a hypothesis test utilizing parametric statistics and an independent sample t-test, contingent upon meeting the necessary criteria. Data on the critical thinking skills of prospective elementary school teachers were input into SPSS software to perform the independent sample t-test. The results of the t-test for independent samples are presented here.

Table 5. Outcomes of the Independent Samples Test

No.	Variables	t-count value	t-table value	Sig. (2-tailed)
1	Critical Thinking Skills	2.656	1.671	0.010

The t-test calculation with the independent sample test type is represented in the table above. These findings indicate that the t-count value (2.656) exceeds the t-table value (1.671), and the sig. Value: $0.010 < 0.05$ (2-tailed). This signifies a disparity in the means observed between the experimental and control groups. The problem-based learning model, augmented by electronic textbooks, substantially affects students' critical thinking abilities. An analysis utilizing the Normalized Gain was performed to ascertain the average enhancement in critical thinking skills among prospective elementary school teachers. The subsequent table illustrates the outcomes of the N-Gain score calculation.

Table 6. Results of the Normalized Gain Test for the Experimental and Control Classes

No.	Group	Normalized Gain Criteria			Normalized Gain Average
		Low	Medium	High	
1	Experiments	13	12	5	0.34
2	Controls	28	2	-	0.13

As shown in Table 6, the majority of the gain values in the experimental class were in the medium gain category and were higher than those in the control class, which were predominantly in the low gain category, according to the results of the normalized Gain test. This implies that the learning process is more effective when facilitated by electronic textbooks and the problem-based learning model than when learning is conducted through regular discussions. This is also evident in the average N-gain score, which indicates that the experimental group is in the medium category with a score of 0.34, whereas the control group has an average N-gain score of 0.13, placing it in the low category.

Discussion

This study's results demonstrate that students' critical thinking skills are markedly enhanced when the problem-based learning model is utilized in conjunction with electronic textbooks. The results of statistical tests indicate that the t-count value (2.656) exceeds the t-table value (1.671). In problem-based learning, students are prompted to examine authentic issues that enhance their critical thinking abilities. According to the pertinent theory, problem-based learning offers a genuine problem context that motivates students to analyze, evaluate, and devise solutions both independently and collaboratively (Treepob et al., 2023; Widayati & Khofifah, 2022). Furthermore, problem-based learning is a learning model that involves students as active participants in the resolution of intricate contextual issues (Pitorini et al., 2025; Simanjuntak et al., 2021). In this process, students not only remember information but are required to identify problems, analyze data, formulate arguments, and evaluate solutions, all of which are indicators of critical thinking skills (Indriani et al., 2023; Rofiq, 2019).

The use of electronic textbooks as supporting media in the PBL model provides an important contribution. Electronic textbooks can be accessed and used flexibly, and the presentation of materials is interactive (Chen et al., 2024). Electronic textbooks can facilitate students to explore information in more depth according to problem-based learning needs. This is in line with the opinion of Aulia et al., (2023) that the digital generation tends to learn with a visual approach and technology that supports speed and flexibility. Relevant opinions also say that electronic textbooks allow the presentation of materials visually, interactively, and easily accessible at any time (Jazuli et al., 2018; Setyowati & Satrio, 2025).

The enhancement of students' critical thinking skills is evidenced by their capacity to identify problems, interpret information, evaluate arguments, and propose logical solutions (Amhar et al., 2022; Suhirman et al., 2021). Students' active involvement in group discussions, searching for additional learning resources, and reflecting on the solutions proposed in each problem scenario are important parts of forming critical thinking patterns (Net et al., 2024). Furthermore, these results are consistent with numerous prior studies that have demonstrated the efficacy of PBL in enhancing

critical thinking and other advanced cognitive abilities (Aziz et al., 2016; Nurfathurrahmah, 2018; Rofiq, 2019; Widayati & Khofifah, 2022). Thinking skills, or activities that help students gain understanding, process information, and conclude, are factors that can support them in learning more effectively. Critical thinking refers to an individual's ability to examine thoughts or concepts more precisely, applying their skills and relevant information (Baharuddin et al., 2022).

The results of this study are also consistent with those of Leny et al., (2024), who found that the use of electronic teaching materials presenting content in an engaging, real-world, and interactive manner helps enhance critical thinking skills. The incorporation of digital media, including electronic textbooks, aligns with the findings of the study by Jazuli et al., (2018), which indicates that technological utilization in education can enhance student engagement and comprehension. The integration of the PBL approach with electronic textbooks fosters a learning environment that promotes active, reflective, and significant learning, thereby enhancing students' critical thinking abilities. In line with the statement of Leny et al., (2024), the teaching materials and learning models used in the learning process play a crucial role in supporting effective learning.

This study has several strengths, including the integration of the Problem-Based Learning model with an interactive electronic textbook, creating an engaging, modern learning experience aligned with the needs of students in the digital era. This approach provides empirical evidence that integrating technology into learning can significantly enhance students' critical thinking skills. Furthermore, the electronic textbook used in this study functions not only as a learning resource but also as a medium that guides students to analyze and solve problems independently. The implications of this research suggest that educators can use it as a reference for designing more engaging and student-centered learning experiences. For students, implementing this model can foster independence and enhance critical thinking skills.

This study has several limitations that should be noted. First, the research was conducted within a single study program with a limited sample size, making it difficult to generalize the findings to broader contexts or other fields of study. Second, the study focused solely on one dependent variable, critical thinking skills, without considering other factors such as motivation, creativity, or collaborative learning, which may also influence learning outcomes. Based on these limitations, it is recommended that future research involve larger and more diverse samples to produce more representative results. Additionally, subsequent studies could include other variables such as learning motivation, creativity, or collaborative skills to provide a more comprehensive understanding of the effectiveness of the Problem-Based Learning model supported by electronic textbooks in improving the quality of higher education learning.

CONCLUSION

Based on the findings, it can be concluded that the implementation of the Problem-Based Learning (PBL) model supported by electronic textbooks has a significant effect on improving students' critical thinking skills. This finding indicates that problem-based learning integrated with interactive digital media can foster a more active, reflective, and meaningful learning experience for students. The novelty of this study lies in the integration of the Problem-Based Learning model with a contextually and interactively designed electronic textbook, offering a new approach to instructional development in the digital era. The results of this study have implications for the future of higher education, promoting a transformation toward more innovative, digital, and student-centered learning. Therefore, these findings can serve as a foundation for lecturers and educational developers to continue integrating technology into teaching practices that nurture students' higher-order thinking skills.

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The effect of augmented reality-based Snake and Ladder game on early childhood cognitive development

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ABSTRACT

This study examines the impact of an Augmented Reality (AR)-based Snake and Ladder board game on improving early childhood cognitive abilities. Conventional learning often causes boredom and limits children's creativity, so innovative media that stimulate reasoning and imagination are needed. Using the Research and Development (R&D) method with the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), this research involved 26 children at Bustanul Athfal Sragi Kindergarten. The analysis phase revealed that children were active, competitive, and curious. The AR-based Snake and Ladder game was designed by integrating physical boards with AR question cards connected to 3D objects in the Assemblr EDU application. Media and material experts validated the product with feasibility scores of 84% and 80%, both categorized as "Highly Valid." Implementation results showed that the AR-based game effectively increased children's interest, enthusiasm, curiosity, and cognitive stimulation through an engaging blend of digital and real-world interaction, aligning with the "learning while playing" principle and fostering early technological literacy. Further research is recommended to explore similar technology-based learning media across different educational contexts, age groups, and subjects to enhance understanding of its effectiveness and long-term educational benefits.



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INTRODUCTION

The development of education today can be characterized by technological advances. In the increasingly competitive and digitally connected global era, early childhood education is faced with a great challenge to ensure that children get optimal developmental stimulation that is utilized by educators as a means in the learning process (Pratiwi et al., 2024). In recent years, the gaming industry, which is looking for a more immersive interactive experience, has developed a series of new devices and technologies that provide users with a more natural interaction compared to a gamepad, keyboard, or a regular mouse (Alzubi et al., 2018). At an early age, the use of games or interactive media can be more effective in supporting their cognitive development. With Information Technology has become very rapidly, it can cause anyone who can access the internet itself quite so, especially for children who are of school age (Purnamasari & Verano, 2024). Understanding how

family dynamics, economic conditions, and social factors shape cognitive ability behaviors is essential for developing targeted interventions, especially for children aged 0–6 years (Khun-inkeeree & Puti, 2025).

In this context, children will have an easier time remembering the information conveyed, thus contributing to the sharpening of their cognitive abilities. However, there are still many educators who rely on manual learning methods or only use guidebooks as a teaching medium. This kind of approach has the potential to create a sense of boredom among students, which in turn can hinder their cognitive development. This can be seen when the teacher delivers the material, where children are often more interested in playing with their friends in the back of the class, without heeding the explanation given by the teacher in front. To provide effective and efficient education for early childhood, educators must understand the factors that can affect their development (Salamah & Sarjiyem, 2025). Therefore, it is important to implement teaching materials that can stimulate children's creativity in the learning process (Ritonga et al., 2022).

Over time, children's development can change according to their way of thinking, solving problems, and understanding concepts (Mulyati & Suryani, 2023). Improving cognitive abilities is one of the aspects that can be developed in kindergarten. In this development, there are many things that can be done to achieve a goal in improving children's learning, one of which can be through games. Board Games (board game) are a type of game that involves moving or placing pieces on a predetermined surface or board. This game is carried out according to the rules that have been set (Mulyati & Suryani, 2023). Deep Board games, the player interacts with a marked board, either by moving pieces or placing them, and all game activities are governed by a set of rules of the game that are set at the beginning (Ningtyas, 2023).

The snake and ladder game is an effective method in increasing students' absorption and understanding of the subject matter, especially for topics that are difficult to understand without the help of the media (Setiawati & Suyadi, 2021). Snakes and ladders are like an interesting educational medium, children are happy, children feel like playing even though in reality this game is learning while playing (Nurhidayati & Imron, 2021). In the Snakes and Ladders game, there are many versions. To make children more interested, this game has been modified; modifications are made by changing the rules of the game (Lestari, 2021).

The snake and ladder game that will be carried out by the researcher is combined with AR (Augmented Reality), which is included in the category of 3D interactive technology. Augmented Reality is a technology that integrates the real world with two-dimensional or three-dimensional elements, which are poured into a container and then projected into the real environment. Through Augmented Reality, users can gain a more immersive interaction experience with the real environment in the form of Virtual (digital) Real-time, so that the experience gained feels more real (Rahma & Ekawati, 2024).

With the help of AR technology, learning materials can be delivered and explained in a more specific and detailed way. Examples of research that implement AR technology in the field of education are the development of AR applications for learning about ancient animals, the development of learning media for the introduction and learning of animals, plants, or others by displaying 3D objects from the learning as researchers are doing today. And many more studies study the implementation of AR technology in learning media (Aji et al., 2023). AR technology can help early childhood learning as a support to get optimal developmental stimulus.

Children aged 0 to 6 years experience a tremendous acceleration in growth and development. This period, which is often called the Golden Age, became the foundation for their future. Accurate and targeted stimulation at this age is vital so that the child's potential can be fully realized. The role of educators and parents is key to ensuring optimal stimulation and alignment with the stages of child development at this golden age. One of the main focuses is cognitive development. At the kindergarten (PAUD) level, cognitive development is designed to equip children with the ability to solve simple challenges, hone their creativity, and understand the world around them. As an illustration in the context of technology-based cognitive stimulation, children can be introduced to interactive picture guessing games, such as counting numbers, mentioning traits with puzzles. Counting activities are carried out to find out the number or quantity and characteristics of an object

(Putri et al., 2024). So that in the explanation of early childhood and children's cognitive abilities, the researcher made a comparison with relevant studies by several previous researchers.

This relevant research will help researchers to improve the validity of the research. The research conducted by the researcher with the title "Influence Board Game Snake Ladder Based Augmented Reality To Improve Children's Cognitive Abilities in Early Childhood Education", while the previous research journal was titled "Development of Media-Based Learning Augmented Reality on the theme of ancient animals to develop cognitive abilities in early childhood group B (5-6) years". The difference between previous researchers and current researchers is that, in the implementation, the previous researchers implemented using AR directly on the theme of ancient animals, while the current researchers implemented using Board games and combined with AR-based technology in all categories according to the age of the child.

The similarities in previous research and current research are that they both use AR-based and improve early childhood cognition. In 2023, Linda Winarni, Rachma Hasibuan, and Umi Anugerah Izzati conducted a study entitled "The Application of Educational Snake and Ladder Game Media in Improving Word Recognition Skills." The difference between the study and the researcher lies in the goal of the researcher, aiming to improve children's cognitive skills, and previous researchers to improve word recognition skills (Winarni et al., 2023). In 2024, a journal entitled "The Use of Causal Snake and Ladder Games in Improving Cognitive Abilities in Early Childhood" was researched by Imamah and Harmiasih, the research has similarities in the goal category, namely to improve early childhood cognition, but there is a difference between the journal and the researcher, namely in the method taken, the previous researcher used the qualitative method while the researcher used the R&D method (Research and Development) (Imamah & Harmiasih et al., 2024).

The purpose of the research conducted by the researcher is to find out how the implementation of AR-based board games affects improving early childhood cognition. In addition, by using the concepts that have been designed, it is hoped that children can understand and improve their reasoning and thinking power about animals or others in board games. With the combination of board games and AR, it will be very beneficial for children, in addition to improving the learning process, so that they don't get bored easily. With this implementation, it is hoped that children can understand the technology-based learning process provided with concrete material through the implementation process between the real world and the virtual world.

METHOD

This research adopts the type of R&D research (Research and Development). At the research stage, data collection was carried out with a qualitative approach. The results of the data collection analysis will be processed at the concept and design development stage using the ADDIE model, which consists of five stages, namely: Analysis, Design, Development, Implementation, and Evaluation (Adnas & Veren, 2023).

The Analysis stage focuses on identifying the learning problems, goals, and needs of early childhood education, as well as the characteristics of learners. The Design stage involves creating learning objectives, determining content, and planning the structure and flow of the AR-based Snake and Ladder game. The Development stage is carried out by producing and integrating physical and digital components of the learning media using the Assemblr EDU application. The Implementation stage involves testing the developed media on early childhood learners to observe its practicality and effectiveness in the learning process. Finally, the Evaluation stage is conducted to assess the overall quality, feasibility, and learning outcomes through expert validation and feedback from users, ensuring that the product meets the desired educational standards.

In R&D (Research and Development) research, the measure of strength found in the demonstration of the research will later explore problems arising from the events experienced, with an example in the kindergarten to be studied does not have many media, with this research expected to meet cognitive needs.

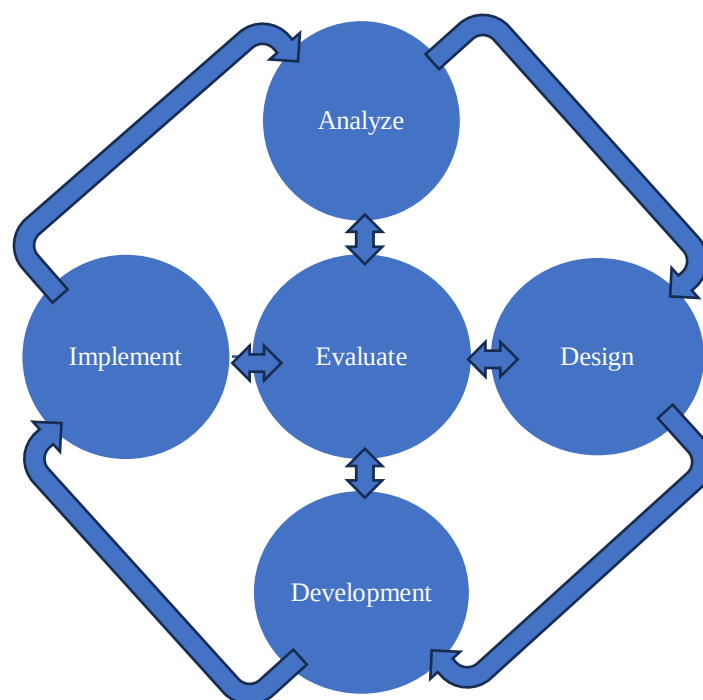


Figure 1. Model ADDIE

In the above stage of the ADDIE development model, it can show the following information:

Analysis

The first stage in the ADDIE development research model is analysis. At this stage, the researcher conducts observations, interviews, and analysis of problems that occur by collecting information to show the basis of the problem and what is needed for early childhood. Observations and interviews were carried out at Bustanul Athfal Sragi Kindergarten with the Principal. The researcher conducted an exploration by asking how the implementation was carried out by the school to attract children so that they could follow learning properly. Thus, the exploratory findings that the researcher got were a form of learning with technology-based games. The selection of technology-based games is also carried out according to the right early childhood needs and the learning goals achieved.

Design

The research model was carried out after the researcher conducted an analysis and learning needs at Bustanul Athfal Sragi Kindergarten, at this stage the researcher conducted an AR (Augmented Reality) based board game learning design, the stage of designing the researcher's board game using a board according to the required size, game rules, questions behind the cards, and dice as support to run the game, as for the AR part, The researcher uses Assembler Edu with 3D & AR technology, in this Assembler EDU feature will help researchers to create a design question or something that can be raised through the QR barcode available on the question card.

Development

The next stage after the researcher models a product is an augmented reality-based board game. Validation on a product will be carried out after this learning media has been completed. This validation will later be carried out by a validator, or it can be called a media expert, to find out the eligibility criteria. Next, the researcher collected data through a questionnaire to see the children's response to a product implemented and several teachers and principals at Bustnaul Athfal Sragi Kindergarten.

Using the questionnaire data that the researcher will later conduct, namely with the assessment criteria of the scale (Likert scale) in Table 1, strongly disagree, disagree, neutral, agree, and strongly agree, as follows:

Table 1. Likert Scale

No.	Category	Range
1	Strongly disagree	1
2	Disagree	2
3	Neutral	3
4	Agree	4
5	Strongly agree	5

The researcher then conducted a validation test using a validation questionnaire through the results of media validation, materials, and validation *post-implementation* from teachers. After the score results appear, the score is calculated as quantitative data to determine the scale of the assessment expressed in percentages. The calculation uses the following formula (Yahya et al., 2020).

$$P = \frac{\sum R}{N} \times 100\% \quad (1)$$

Information :

P : Percentage of the score sought
 $\sum R$: Number of answers given by the validator/selected choice
 N : Maximum number of scores

After obtaining the score percentage, it can then be converted so that the researcher can find out whether the learning tool is valid or not, with the categories of very valid, moderate, less valid, and invalid can be seen in Table 2 in the score percentage category (Setiawan & Rahman, 2025).

Table 2. Score Percentage Categories

No.	Percentage	Description	Category
1	75.01% - 100%	Excellent	Very Valid, can be applied immediately
2	50.01% - 75.00%	Good	Quite valid, usable, and in need of a bit of revision
3	25.01% - 50.00%	Not Good	Invalid, recommended not to use, and needs revision
4.	0.00% - 25.00%	Bad	Invalid, not allowed to be used.

Implementation

The researcher conducted a product trial stage as a learning medium. The trial was carried out with children at Bustanul Athfal Sragi Kindergarten group B1, with a total of 26 children. At this stage, the researcher also conducts an assessment of the child to provide a product result, which will later be continued at the evaluation stage, where this response and assessment will later determine whether the researcher to conduct an evaluation.

Evaluation

The final research phase of ADDIE development, this stage is carried out to determine the value of the results of the trial on the implementation of product trials. The data collection instrument carried out by the researcher was to make a questionnaire filled out by teachers and principals at Bustanul Athfal Sragi Kindergarten.

The learning process is one of the things that can be encouraged through technology in the field of science, so that it can strive for an innovation that can advance learning. Along with its rapid development in the digital era, Augmented Reality (AR) can provide learning and added value in the process, especially in the context of educational games. AR is one of the learning technologies that can improve and attract children to be able to participate in learning in a conducive way and increase children's interactivity. This provides an opportunity to present information more visually and dynamically, so that it can enrich children's creative imagination. This technology is very suitable for use in play groups at Bustanul Athfal Sragi Kindergarten to improve children's cognition (Basri

et al., 2024). In this analysis plan, the researcher creates questionnaire data that will be validated by media experts and material experts, and later, the researcher will obtain data through a questionnaire, which will be analyzed for validity and reliability tests. The purpose of validity test analysis is the purpose of assessing the quality of questions or items in the instrument (questionnaire/questionnaire), while the purpose of reliability is to find out the extent to which the instrument can provide consistent results when used repeatedly.

RESULTS AND DISCUSSION

Results

Research and trial development of learning media products at Bustanul Athfal Sragi Kindergarten group B1. Through quantitative methods with questionnaires and learning development through media, combined with AR (Augmented Reality). The results of the quantitative method and development stages are as follows:

The analysis stage carried out by the researcher to meet the needs of early childhood, the analysis was carried out through observation and interviews of B1 group teachers. On the results of observations carried out in class, the researcher found the active, competitive, and curious nature of the character of the B1 class children. Through these observations, the researcher can conclude that the games to be implemented can arouse the enthusiasm of B1 grade children, because the media mixed with games can provide a challenge for children, by packaging technology using Augmented Reality can make children have reasoning and make cognitive development work better.

In addition to observation, the researcher carried out an interview stage with the classroom teacher, in the interview session the researcher found that there was learning relative to books or just videos, so that the use of less innovative learning media made the child unable to explore further, this refers to the child's cognitive development process, therefore at the analysis stage the researcher provided a solution in the form of board games AR-based snake and ladder for early childhood at Bustanul Athfal Sragi Kindergarten group B1.

Furthermore, the researcher carried out the design stage for Augmented Reality-based media after the implementation of the needs analysis. The media design stage for AR-based snake and ladder board game products is as follows:

1. Snake and Ladder board game design

The design of the Snakes and Ladders board game in this media uses a box-shaped board. This Snakes and Ladders board game consists of:

- a. Box-shaped board with a size of 40cmx40cm
- b. 7 Rules
- c. The stop is carried out when the child enters a box with a snake's head and a ladder up. Two dice, 10 questions.

2. Augmented Reality Design

The use of technology in this Augmented Reality design in the Snakes and Ladders board game has a question card, on the back, some questions will be answered by the child, this is done so that the child can train his cognition by guessing from the questions asked, and the child's answers will be corrected using a barcode that already has the correct answer.

The learning media developed are Board games, snake ladder-based Augmented Reality. Board game made through a combination of manual and technology, while augmented reality is created using an app, Assemblr edu: create 3D and AR. On the manufacturing Board, games can be seen in [Figures 1 to 4](#).



Figure 1. Board Game Snakes and Ladders



Figure 2. Cube



Figure 3. Pawn



Figure 4. Question Card

In digital media, researchers use an Assemblr edu application. This application can be used and downloaded through the Google Play Store, and can be used on a smartphone or laptop, according to conditions. In making question cards or barcodes, you can see the steps in Figures 5 to 10 below.

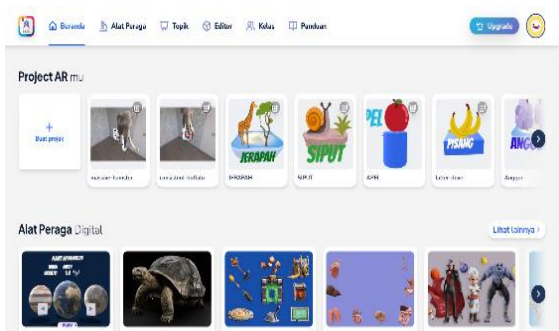


Figure 5. Initial View of the Edu Assembly

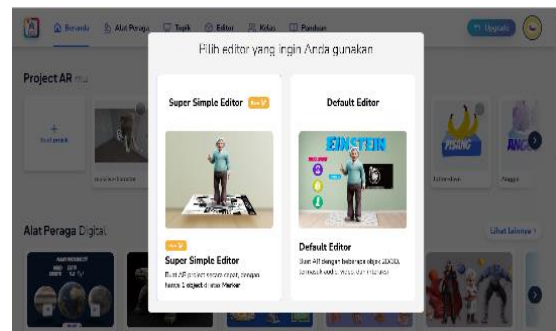


Figure 6. Edit Options Menu

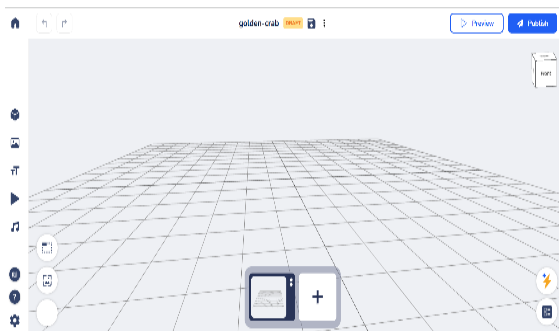


Figure 7. Assemblr Worksheet



Figure 8. Assemblr Edu Worksheet Selection Menu

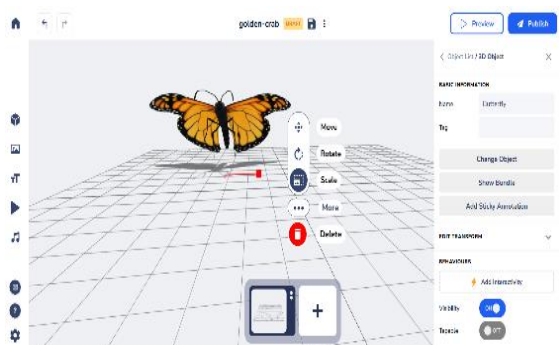


Figure 9. Editing Process



Figure 10. Barcode

After the development media have been created, the next stage is validation by media experts and material experts. The implementation of this validation was carried out with media experts and material experts filling out questionnaires and providing suggestions and improvements to researchers. The results of media and material validation can be seen in [Tables 3](#) and [4](#). The following are the results of validation by media experts and material experts.

[Table 3](#). Media Validation Results

No.	Indicators	Percentage
1	Design and visualization aspects	86%
2	Feasibility aspects of use in various conditions	86%
3	Security and privacy aspects	90%
4	Media aspect	80%
5	Image quality	80%
Sum		84%

[Table 4](#). Material Validation Results

No.	Indicators	Percentage
1	Suitability of the material to the child's age and cognitive development	76%
2	Diversity of materials and challenges in <i>board games</i>	75%
3	Simplicity and clarity of material	80%
4	Influence on the understanding of learning materials	90%
Sum		80%

After being declared valid by media experts and material experts, the researcher implemented a question-and-answer learning model using an Augmented Reality-based Snakes and Ladders board game media. In the learning session, the researcher conducts learning about the theme that will be carried out as referred to the implementation of the Augmented Reality-based snake and ladder board game to improve cognition through exploration of learning that is innovated through the digital world in the form of a barcode and behind it is a question in the form of a puzzle question that will be answered by B1 grade children, and the answer through a barcode can be seen in [Figure 11](#) below.



[Figure 11](#). Barcode Implementation

[Table 5](#). Board Game Implementation Questionnaire Results

No.	Indicators	Percentage
1	Gaming board media display	80%
2	Ease of access and use of media	80%
3	AR media interactivity	80%
4	The effectiveness of using AR media	80%
5	Utilization of media in cognitive development	80%
Sum		80%

At the implementation stage, learning media in the form of Augmented Reality-based board games need to go through an evaluation process. This evaluation aims to improve the final product by considering the input and suggestions for improvement provided by teachers during the implementation stage in schools. In this study, the evaluation process is carried out by referring to the results of assessments and recommendations from experts (validators), which are then submitted to teachers as feedback on the media that has been developed. The assessment is an important reference in evaluating and perfecting Augmented Reality-based board game learning media for development in the next stage. The results of the implementation questionnaire that were forwarded at the evaluation stage showed a figure of 80% which, if referring to the percentage category of score, was declared to be very valid, but there is little that must be revised so that board game learning media can be implemented for a long time.

Discussion

On the implementation of the use of technology through the Snakes and Ladders board game learning, Augmented Reality is a way to make the child's curiosity grow, and it can improve the child's cognition. Students are interested in the visualization of objects that are difficult to see in real life and appear on smartphones that teachers use (Nasution et al., 2022). The use of media as a learning tool is essentially an integral part of early childhood learning management planning (Rais et al., 2024). Rapid technological advances have brought significant changes to educational media, which were traditionally based on conventional methods but can now be implemented more practically using digital tools (Mukhlisin et al., 2025). To identify the impact of AR game-based learning on children, the app was evaluated to determine the efficiency, effectiveness, user engagement, and learning ability of children (Farooq et al., 2022). AR designers can use new technologies, but make sure they don't interfere with the logical narrative, the player's imagination, and their social relationships. Therefore, at least at this stage, AR should be used to support, not replace, the human imagination (Laato et al., 2021). So it is very important that teachers can use learning that can make children interested and enthusiastic to carry out learning, by involving the digital world into learning it can be concluded that children are very interested in digital-based learning resulting from the use of assemblr edu, with the opportunity to learn directly with assemblr edu, children can establish direct interaction with virtual objects that seem to be present in the real world, which is certainly in line with the principle of "learning while playing" with 3D drawings (Hafifah & Marlina, 2025).

The results of media and material validation are the percentages that can produce feasible and unfeasible ones. The result of the percentage score of the researcher after going through several stages in the media validation category was 84% with the very valid category, from the results of the material validation was 80% with the very valid category, from the final percentage results both were very valid and could be implemented in early childhood, so the researcher hopes that with a good percentage, both media and material can be done well it aims to improve children's cognition. The final results of the researcher concluded that children's learning combined with the digital world can make children more curious and more active in participating in learning, thus many benefits can be gained and developed through digital-based learning, one of which is that it can improve children's cognition. AR technology can serve as a very effective tool not only to improve cognitive abilities but also to encourage creative thinking and active learning (AlAli & Al-Barakat, 2024).

The researcher agrees with a journal study by Alzahrani (2025), who, in his research, found that one of the unexpected findings is that many teachers use technology and are ineffective in their lessons. Although teachers claim to use technology, its use is limited to administrative purposes or to provide knowledge as a means of supporting traditional methods (Alzahrani, 2025).

The benefits of Assemblr Edu certainly do not escape the curiosity of children can be paid off by presenting a virtual learning experience, so that this can include children's learning with exploration through the digital world. By utilizing Assemblr Studio, children not only learn about learning materials but also hone technological skills that will be useful in their lives in the future (Hamidah et al., 2024). The effectiveness of integrating technology in the assessment and learning

process demonstrates the feasibility of similar use in other subjects or educational environments (Darmawan & Septyanti, 2024).

The results of the study show that the application of Augmented Reality (AR)-based Assembler EDU technology is effective in increasing involvement, interest in learning, and understanding of early childhood concepts. The integration of this technology is able to create a more interactive, visual, and contextual learning experience, thus encouraging the creation of a meaningful and enjoyable learning process. Thus, Assembler EDU can be used as an innovative learning medium that supports the application of 21st-century learning in early childhood education.

This study still has limitations on the limited scope of subjects and the relatively short duration of application, so the results cannot be generalized widely. In addition, the study has not examined in depth the effect of the use of Assembler EDU on other aspects of development, such as children's social-emotional and motor skills. Therefore, further research is recommended to involve a more diverse sample, longer implementation duration, and more comprehensive measurement of variables to obtain more in-depth and representative results.

CONCLUSION

The implementation of the Augmented Reality (AR)-based Snake and Ladder board game has a significant positive influence on improving early childhood cognitive abilities at Bustanul Athfal Sragi Kindergarten. Through the Research and Development (R&D) approach with the ADDIE model, innovative learning products have been developed and validated with very satisfactory results from media experts (84%) and subject matter experts (80%), confirming their feasibility of use. The use of AR technology in the board game Snake and Ladders has proven to be effective in overcoming children's learning saturation that often arises from conventional methods. Children show higher enthusiasm, curiosity, and engagement due to the interactive and dynamic visualization of 3D objects that appear on smartphones. The learning process becomes more interesting and concrete, allowing children to understand and develop their reasoning and thinking power optimally, especially related to the material presented in the game. The integration of physical board games with AR digital elements creates an immersive "learning as play" experience, supporting the stimulation of cognitive development that is essential in a child's golden age. Therefore, digital-based learning media such as the AR-based Snake and Ladder board game are highly recommended to be applied to encourage educational innovation and optimize early childhood cognitive development. In the next study, it is recommended that wider development be carried out on the application of similar technology-based learning media in various contexts, age levels, and fields of learning, in order to gain a deeper understanding of its effectiveness and sustainability in supporting the children's education process.

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Statistics learning innovation through contextual numeration of literacy e-module

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ABSTRACT

The numeracy literacy skills of Indonesian students, particularly in solving story problems and presenting statistical data, remain relatively low. However, teaching materials that effectively support numeracy literacy in mathematics are still limited. This study aims to describe the development of a numeracy literacy e-module as an alternative teaching material for statistics. Using a Research and Development approach within the ADDIE model, the study was conducted through the implementation stage due to time constraints. Participants included 30 seventh-grade students from Junior High School 2 Kuningan. Data were obtained from expert validation and student response questionnaires and analyzed descriptively using percentages. Validation results from material and media experts were 90.62%, 95.31%, and 94.12%, categorized as very valid. Student responses indicated a practicality level of 91.33%. The contextual story-based e-module effectively connects statistical concepts to real-life situations. The findings conclude that the developed e-module is highly valid and practical for classroom use. However, implementation faces challenges, including limited teacher training and inadequate digital infrastructure. Therefore, teacher training and better digital support are recommended, along with further studies to evaluate the long-term effectiveness of the e-module.



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INTRODUCTION

Numeracy literacy is a crucial competency that learners need to develop in order to tackle the challenges of the 21st century. This skill encompasses the capacity to think logically, critically, and solve problems, which is vital for everyday activities (Deda et al., 2023). However, the educational landscape in Indonesia indicates that students' numeracy literacy skills remain quite low. This observation is corroborated by the outcomes of national assessments and international studies that emphasize the inadequate performance of students in numeracy (Kaize et al., 2024). For instance, the PISA 2022 results reported that Indonesian students achieved an average mathematics score of 379, significantly below the OECD average of 472, placing Indonesia in the bottom quartile globally (OECD, 2023). Similarly, data from the Minimum Competency Assessment (AKM) 2021 revealed that only about 25% of students reached the "proficient" level in numeracy, while the majority remained in the "basic" or "below basic" categories (Kemdikbudristek, 2021). A primary factor

contributing to this issue is the teaching approach to mathematics, which lacks contextualization and relevance to students' everyday experiences. Thus, the importance of learning mathematics lies in structuring students' abilities, one of which is mathematical communication skills, which must be emphasized as an essential focus in mathematics learning (Shabrina et al., 2023).

Statistics is a component of the mathematics curriculum that holds significant promise for enhancing numeracy skills. Statistics is one of the important fields of study in learning activities. Statistics plays a role in managing pocket money, profits and losses in trading, recording student grades, and others (Hidayati & Djamaan, 2025). This area emphasizes the importance of data reading, information interpretation, and making decisions based on data (Kurniawan et al., 2022). Unfortunately, the approach to learning statistics in schools tends to be heavily theoretical and abstract. Educators often present questions that are mechanical and lack a meaningful connection to students' real-life contexts (Suratman & Pranata, 2024), leading to students struggling to grasp concepts and apply them in everyday situations.

To address this issue, employing a contextualized story problem method has proven to be an effective strategy. Contextual maths problems are mathematical problems that are related to context, either directly related to real objects or related to abstract objects such as mathematical facts, concepts, or principles (Agnesti & Amelia, 2020). This method not only presents problems that resonate with students' experiences but also enhances their understanding of concepts through relevant situations (Hasibuan et al., 2023). By utilizing this approach, students are motivated to think critically, evaluate information, and devise solutions rooted in real-life contexts (Azubuike et al., 2024). This makes the educational experience more engaging and challenging.

Learning mathematics is a basic science, so it is needed in the learning process. Mathematics and critical thinking skills are interconnected; this critical thinking will train students to get used to working on small steps first before they can then be adept at higher-level critical thinking (Rahmaini & Chandra, 2024). Nowadays, critical thinking skills are very important in daily life because they develop other thinking skills, such as the ability to make decisions and solve problems (Saputra, 2020). Critical thinking is essential in mathematics education, particularly when addressing intricate problems. Learners must not only arrive at solutions, but they must also be capable of analyzing data, assessing information, and presenting sound arguments (Fristadi & Bharata, 2015). Contextualized story problems offer an opportunity to exercise these skills by presenting genuine challenges that require thoughtful and profound reasoning (Azubuike et al., 2024).

Despite this, the reliance on printed teaching resources, like traditional modules, remains prevalent and comes with several drawbacks. Such printed modules are often static, lack interactivity, and cannot offer instant feedback. Their inability to cater to the unique needs of individual students also restricts the enhancement of self-directed learning (Maruyama & Igei, 2024). This is why e-modules serve as a strategic alternative for delivering learning that is more adaptable, engaging, and contextually relevant.

Yet, there is still a lack of research that specifically focuses on creating e-modules for numeracy literacy with a contextual story problem approach in statistics education. In contrast to the study by Hasibuan et al., (2023), which only looks into the use of contextual story problems in a broad sense, this research homes in on developing e-modules intended to enhance students' numeracy literacy in statistics learning. This e-module not only presents mathematical material, but also contains contextual problems that can guide students in solving problems related to numeracy, so that they are able to analyse, formulate problems, solve problems, and present in various forms and situations (Safitri et al., 2023). This focus is a vital foundation for researching to create innovative teaching materials that meet the needs of contemporary students (Leon et al., 2025). When compared with previous studies, several similarities and differences highlight the contribution of the present research. In terms of similarities, both this study and the works of Zawacki-Ritchter et al., (2019) and Dogan et al., (2023) employed a systematic framework for developing digital learning media. However, differences can be observed in the focus and outcomes produced. Earlier research often emphasizes the development of alternative media, such as AI-powered learning systems, personalized learning platforms, adaptive educational technologies, and collaborative digital environments that stress interaction among teachers, students, and technology (Bozkurt et al., 2021; Leon et al., 2025).

In contrast, the present study concentrates on the development of a numeracy literacy e-module centered on contextual problem-solving in statistics, directly aligned with the requirements of the Minimum Competency Assessment (MCA) and the implementation of the Merdeka Curriculum. Thus, the unique contribution of this research lies in the explicit integration of numeracy literacy within the design of a digital e-module, an aspect that has not been extensively explored in previous studies, thereby reinforcing its relevance to both educational media innovation and national education policy. This method offers several benefits, including the capacity to connect students with authentic situations through relevant and demanding challenges. Prior studies indicate that problems rooted in context can enhance students' comprehension of mathematical concepts and numerical literacy (Rochsun & Agustin, 2020). Additionally, e-modules as digital tools provide flexibility, facilitating self-directed learning, digital literacy, and the application of Minimum Competency Assessment (MCA).

Given this context, the goal of this research is to create e-modules focused on numeracy literacy that utilize a contextual story problem approach in teaching statistics. This study is anticipated to significantly enhance students' numeracy literacy, foster critical thinking abilities, and render the learning of statistics more relevant, engaging, and enjoyable. By presenting statistical concepts through real-life scenarios, the e-module encourages students to connect mathematics with their daily experiences. This not only strengthens conceptual understanding but also builds confidence in problem-solving (Maruyama & Igei, 2024). Furthermore, the digital format of the module provides opportunities for interactive learning, making it a practical and adaptive resource for both students and teachers in modern classrooms (Jamaan & Yerizon, 2023). The use of relatable scenarios in the modules helps students see the practical value of statistical concepts in everyday life. This approach also encourages active learning, where students are not only solving problems but also interpreting data and drawing meaningful conclusions. As a result, the learning process becomes more student-centered and supports the development of 21st-century skills.

METHOD

The study employs a research and development (R&D) dengan menerapkan langkah-langkah pengembangan model ADDIE (Analyze, Design, Develop, Implementation, Evaluation). The approach is primarily aimed at creating interactive e-modules that utilize contextual story problems related to statistics, which can enhance students' numeracy skills (Kusna et al., 2023). The R&D method was selected as it offers a structured and accountable strategy for developing or improving products to increase their effectiveness in the educational process (Afriani et al., 2025). Moreover, this method highlights the significance of creating media that aligns with various learning styles to bolster student achievement (Adiastuty et al., 2024). The development framework applied is the ADDIE model, which includes five phases: Analysis, Design, Development, Implementation, and Evaluation. Each phase is conducted in a sequential and systematic manner to guarantee that the resulting product meets the students' needs and possesses high-quality content, aesthetics, and effectiveness (Afriani et al., 2025; Alifiya & Sabandar, 2023). The procedure/stages of product development are illustrated below.

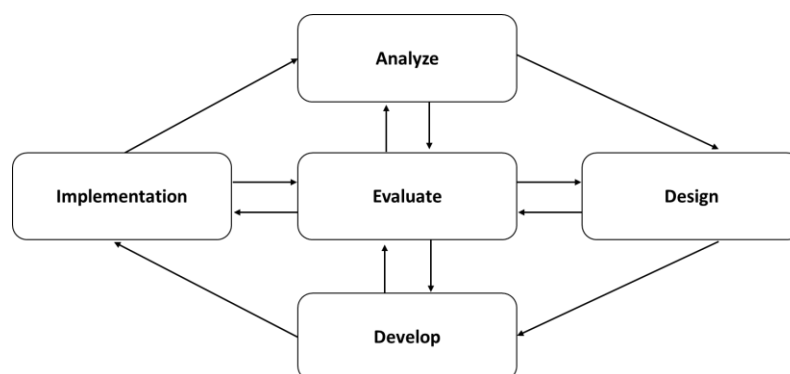


Figure 1. ADDIE Model Flowchart

This study took place at Junior High School 2 Kuningan from January to June 2023 during the 2022/2023 academic year. The data collection commenced with interviews with teachers on February 7, 2023, aimed at understanding the needs for teaching materials and the current state of statistics education in the classroom. In addition, a field trial was carried out with students on May 30, 2023, to assess the effectiveness of the developed product and gather their feedback. The participants in this research consisted of 30 students from class VII at Junior High School 2 Kuningan, who were chosen through a purposive sampling method based on their availability and willingness to take part in the product trials. The design adopts a quasi-experimental pre/posttest with a comparison group, or at a minimum, a single-group pretest–posttest design.

The study utilized several instruments, including: (1) an expert validation sheet aimed at evaluating the content, presentation, and media elements of the developed e-module, which was assessed by two expert lecturers specializing in learning media; (2) a student response questionnaire utilizing a 4-point Likert scale to gauge the e-module's readability, appeal, and usability; and (3) a set of interview guidelines for teachers to investigate learning needs and challenges faced by students in comprehending statistics material. The collected data were analyzed through both quantitative and qualitative methods. Quantitative data, derived from validation findings and student response questionnaires, were processed using descriptive percentage analysis to ascertain the validity and practicality levels of the product. On the other hand, qualitative data, including insights from teacher interviews, were examined through thematic analysis to outline learning needs and the context surrounding students' difficulties in grasping statistics material (Fauziyyah et al., 2024). Validity testing focuses on determining whether the developed media accurately reflects the intended content, instructional design, and technical aspects, as evaluated by experts in the field. A valid learning medium must meet standards of accuracy, relevance, and appropriateness, ensuring that it can effectively support learning objectives. Practicality testing, on the other hand, emphasizes the usability and applicability of the media from the perspective of its users, including students and teachers. This process examines whether the media is easy to use, engaging, and able to facilitate learning activities in real classroom conditions. A learning medium that meets both validity and practicality criteria can be considered suitable for broader implementation, as it not only aligns with educational standards but also addresses the needs and experiences of its users.

Table 1. Criteria for Validity Assessment Percentage

No.	Assessment Percentage	Criteria
1	$X < 37.5\%$	Not Valid
2	$37.5\% \leq X < 62.5\%$	Less Valid
3	$62.5\% \leq X < 87.5\%$	Valid
4	$87.5\% \leq X < 100\%$	Very Valid

Based on Table 1, the learning media is considered feasible for implementation to students if it achieves an average validator score of 62.5%–87.5% with the “valid” category and an average validator score of 87.5%–100% with the “very valid” category. If the developed learning media obtains an average score of less than 62.5%, it is deemed not feasible for implementation. The level of practicality of the developed learning media can be seen in Table 2.

Table 2. Practicality Criteria of Learning Media

No.	Interval	Criteria
1	$76\% < P \leq 100\%$	Very Practical
2	$51\% < P \leq 75\%$	Practical
3	$26\% < P \leq 50\%$	Not Practical
4	$0\% < P \leq 25\%$	Very Impractical

Based on Table 2, if the results fall within the interval of 51%–75%, the differentiated learning media is categorized as practical. Meanwhile, if the average practicality score falls within the interval of 76%–100%, it is categorized as very practical. This indicates that differentiated learning media meeting the practicality criteria can support students in the learning process. Conversely, if the results fall below 51%, the learning media cannot effectively support students in the learning process. To eliminate any confusion, some important terms in this study are clarified. E-modules are defined as

interactive digital resources created to aid in learning statistics through real-life contextual story problems (Sumarni et al., 2023). Numeracy literacy refers to students' capability to comprehend, apply, and interpret mathematical information in practical situations (Rosjanuardi & Juandi, 2023). Contextual story problems are those derived from scenarios or experiences that resonate with students' everyday lives (Yuliani & Chotimah, 2023), while statistics is regarded as a branch of mathematics that involves the collection, processing, analysis, and interpretation of data aimed at solving problems (Zahran et al., 2024).

RESULTS AND DISCUSSION

Results

The creation of e-modules for numeracy literacy focusing on data presentation for seventh-grade junior high school students was executed using the ADDIE model, which consists of the phases of Analysis, Design, Development, Implementation, and Evaluation. This development aims to produce valid, practical teaching materials based on contextual problem stories that can be utilized in mathematics instruction, thereby enhancing students' numeracy literacy abilities.

During the Analysis phase, discussions were held with mathematics instructors at Junior High School 2 Kuningan to pinpoint learning requirements. The teachers indicated that students struggled to comprehend contextual problems related to statistics material. They also conveyed the necessity for more engaging and contextually relevant teaching resources. These findings are supported by literature reviews (Ismanto, 2022) that indicate the effectiveness of e-modules based on numeracy literacy in improving learning outcomes and aiding students in grasping concepts more effectively. (Hidayanthi et al., 2024).

The design phase involves creating e-modules following phase D of the Merdeka Curriculum. These modules are formatted in A4 portrait size, utilizing Arial font at size 13 with 1.5 line spacing. In addition, researchers prepared supporting tools, such as validation sheets for material and media experts, along with questionnaires for learner feedback. The e-module is systematically structured, comprising a cover page, preface, table of contents, e-module map, usage instructions, learning outcomes and objectives, subject content and sample questions, exercises and assessments, summary, answer key, glossary, and bibliography.

During the Development phase, researchers gathered relevant contextual stories and questions. The module was created using Canva to ensure it has an appealing design. Once the prototype was completed, it underwent validation by two material experts and one media expert. Revisions were implemented based on feedback from the validators concerning language, illustration modifications, color contrast, and the layout, including page margins. The cover of the e-module is depicted in Figure 2. Figure 3 presents the access barcode that can be scanned to access the e-module online.



Figure 2. Cover and Mind Mapping of E-Module



Figure 3. Barcode E-Module

The Implementation phase was conducted as a limited trial with 30 students from class VII Junior High School 2 Kuningan during the even semester of the 2022/2023 academic year. The focus of the implementation activities was on familiarizing students with the e-module structure and collaboratively solving statistical story problems. Observational results indicated that students effectively utilized the module and were actively engaged in the learning process.

Validation by two subject matter experts confirmed that the e-module was deemed highly valid. According to the quantitative data conversion results, the first validator rated 6 indicators in the 'valid' category and 10 indicators in the 'very valid' category, while the second validator assessed 4 indicators as "valid" and 12 indicators as 'very valid'. Table 3 summarizes the findings from the validation by the material experts, showing that the average validity percentage is 94.12%, falling into the 'Very Valid' category. Suggestions from the validators included recommending the use of more eye-friendly colors that are not overly bright.

Table 3. Material Expert Validation Results

No.	Indicators	Material Expert 1			Material Expert 2		
		Score	Percentage	Note	Score	Percentage	Note
1	Self Instructional	27	96.42%	Very Valid	25	89.28%	Very Valid
2	Self Contained	4	100%	Very Valid	3	75%	Valid
3	Stand Alone	4	100%	Very Valid	4	100%	Very Valid
4	Adaptive	3	75%	Valid	4	100%	Very Valid
5	User Friendly	12	100%	Very Valid	11	91.66%	Very Valid
6	Numeracy Literacy	11	91.66%	Very Valid	11	91.66%	Very Valid
Average Value			90.62%	Very Valid		95.31%	Very Valid

The cover page and content map of the e-module are illustrated in Figure 1, while Figure 2 displays the access barcode that can be scanned to access the e-module online. Validation carried out by media expert Mr. Erlan Darmawan, M.Pd, utilized 17 assessment indicators. The e-module received a total score of 64 out of a possible 68, resulting in a validity percentage of 94.12%, placing it in the 'Very Valid' category. Table 4 provides a summary of the media expert validation results. Suggested improvements included replacing the word 'you' with a more formal term, ensuring that illustrations align with the content, removing page numbers from the cover, and verifying margins and spelling.

Table 4. Media Expert Validation Results

No.	Indicators	Score	Percentage	Description
1	Language Usage	10	83.33%	Very Valid
2	Content Attractiveness	23	95.83%	Very Valid
3	Layout Appropriateness	31	96.87%	Very Valid
Average Value			94.12%	Very Valid

Additionally, the e-module's practicality was assessed through questionnaires completed by teachers and students. The teacher scored 49 out of a maximum of 52, which converts to a percentage of 94.23%, categorizing it as 'Very Practical.' A total of 10 students also participated in the practicality questionnaire, achieving an average score of 451 out of 500, equating to a percentage of

90.2%, thus also rating it as ‘Very Practical.’ Table 5 summarizes these results, indicating that the e-module is user-friendly, easily comprehensible, and encourages active and meaningful learning.

Table 5. Media Expert Validation Results

No.	Indicators	Score	Percentage	Description
1	Quality of E-modules	445	92.70%	Very Valid
2	Ease of Use	324	90%	Very Valid
3	Learning Implementation	327	90.83%	Very Valid
Average Value			91.33%	Very Valid

Considering the validation and implementation findings, this numeracy literacy e-module, grounded in contextual story problems, is deemed very valid and very practical, making it suitable as an innovative instructional material for junior high school mathematics education. The implementation phase was conducted as a limited trial involving 30 students from class VII at Junior High School 2 Kuningan during the even semester of the 2022/2023 academic year. The focus of the implementation activities was on familiarizing students with the e-module structure and collaboratively solving statistical story problems. Observational results revealed that students effectively utilized the module and actively participated in the learning process.

Validation conducted by two material experts indicated a strong endorsement of the e-module's validity. According to the quantitative assessment results, the first validator classified 6 indicators as ‘valid’ and 10 as ‘very valid,’ whereas the second validator rated 4 indicators as ‘valid’ and 12 as ‘very valid.’ Table 1 summarizes the material expert validation results, showing that the average validity percentage is 94.12%, placing it in the ‘Very Valid’ category. Feedback from the validators included recommendations to use colors that are more soothing to the eyes and not overly bright.

For the effectiveness testing, a paired sample analysis was conducted to compare students’ numeracy performance before and after using the numeracy literacy-based e-module. The results showed that the average numeracy score increased from Mean = 62.3 (SD = 8.5) in the pretest to Mean = 78.6 (SD = 7.9) in the posttest. The paired sample t-test yielded a statistically significant difference ($t = 7.21$; $p < 0.001$), indicating substantial improvement. Furthermore, the effect size was calculated as Hedges’ $g = 0.82$, which is classified as high, suggesting that the intervention had a strong impact. These findings demonstrate that the implementation of the numeracy literacy-based e-module has the potential to produce meaningful improvements in students’ learning outcomes, particularly in mastering the topic of data presentation.

Discussion

In the subject of mathematics, statistics is one of the materials that are considered difficult by students (Kaize et al., 2024; Taram et al., 2019). Therefore, this study resulted in the creation of a numeracy literacy e-module centered on contextual story problems specifically tailored for seventh-grade junior high school learners, focusing on the statistical representation of data. The choice of e-modules as educational resources is driven by the necessity of integrating technology into teaching, alongside the desire for media that is interactive, engaging, and adaptable (Engelbrecht & Borba, 2024). Findings indicate that this e-module is both valid and highly practical for use, as demonstrated by expert validation results and favorable feedback from students.

The development process followed the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), although this study only progressed as far as the Implementation phase due to time limitations. Consequently, the methodology can be more accurately referred to as the ADDIE model (Hidayat & Nizar, 2021). During the analysis phase, literature reviews and interviews conducted at Junior High School 2 Kuningan revealed that students continue to struggle with understanding contextual story problems that involve numerical data. Furthermore, teachers indicated a need for supplementary teaching materials that enhance numeracy literacy education in line with the Merdeka Curriculum (Saa, 2024; Vhalery et al., 2022).

The design of the e-module emphasizes the presentation of statistical content, incorporating contextual story-based evaluation questions that highlight skills in data interpretation, graph reading, and decision-making based on numerical data. The structure of the module adheres to the standard

format (Taufik & Adiastuty, 2024), which includes a cover page, preface, table of contents, module map, content material, exercises, assessments, a summary, answer key, glossary, and bibliography. Created in A4 portrait orientation, the module was developed using the Canva application to enhance its visual appeal and accessibility.

During the implementation phase, the e-module was tested on a small scale with 30 students. While it has not yet been fully incorporated into regular instruction, the pilot indicated that students were able to navigate the module's structure and expressed interest in engaging with it. This highlighted the benefits of e-modules in terms of flexibility, accessibility, and visual attractiveness (Sugihartini & Jayanta, 2017). Nevertheless, some drawbacks were identified, such as the limited number of questions, reliance on an internet connection, and inconsistent infrastructure (Demirkan, 2019; Nouraey & Al-Badi, 2023).

The validation process was carried out by two experts in materials and one in media. The average validity scores from the two material experts were 90.62% and 95.31%, while the media expert provided a score of 94.12%. According to the criteria established by Kemendikbudristek (2021), this e-module falls into the 'Very Valid' category. Additionally, the validation indicates that the e-module meets key characteristics such as being self-instructional, self-contained, standalone, adaptive, and user-friendly. Suggestions for improvements, including color adjustments, more formal language, and layout changes, have been considered for product revisions to enhance its effectiveness.

The practicality was evaluated using a questionnaire filled out by students, which focused on content quality, ease of use, and the implementation of learning. The findings revealed a practicality percentage of 91.33%, suggesting that the e-module is both enjoyable and very easy to use. This aligns with the research (Firmansyah & Rusimanto, 2020), which categorizes e-modules as practical when they score above 63%. Furthermore, some students offered feedback to correct typos, reflecting their active engagement in the evaluation of the learning media.

Moreover, the findings from this research offer significant contributions to the domain of educational administration and management. Viewed from an educational leadership angle, this e-module represents a form of innovative learning that school principals may adopt to promote the integration of technology within educational institutions. Regarding educational planning and policy, the creation of digital teaching resources aligns with the objectives of the Merdeka Belajar policy, which emphasizes personalization, contextualization, and the enhancement of numeracy literacy skills. From the perspective of educational economics, utilizing e-modules can lower the production expenses associated with physical educational materials and facilitate broader distribution that is not limited by geography. Politically, this innovative approach aligns with the government's priority initiatives aimed at improving the quality of technology-based education and meeting national numeracy benchmarks.

Nonetheless, this study does have several limitations. First, the scope of the material is confined to the topic of data presentation for grade VII, which does not encompass a broader range of subjects or educational levels. Second, the implementation was conducted on a limited scale and for a short duration, without being incorporated into a comprehensive learning process. Lastly, this e-module has yet to be linked with a specific learning strategy (such as problem-based learning or the discovery learning model), which could enhance its overall effectiveness.

This limitation suggests avenues for future studies, such as broadening the range of e-module content to cover different mathematics subjects, evaluating how long-term usage affects student learning results, and incorporating e-modules with specific learning approaches geared towards enhancing problem-solving and critical thinking abilities. Additional research can also examine the administrative aspects of schools in implementing innovative digital teaching resources as part of enhancing technology-driven school governance.

Therefore, the findings of this study not only influence classroom learning but also reinforce systemic initiatives aimed at the advancement of educational innovations that promote the enhancement of numeracy literacy within the framework of educational management policies and practices. The discussion also outlines the contribution of research results or findings to relevant fields, especially educational administration/management, consisting of educational leadership, policy and planning, academic economics, and educational politics. The discussion also outlines the

limitations of the research and its implications for practice and research opportunities in the future. We recommend that the words in the discussion are at least 70% of the words in the results.

Recent research further validates and enriches the findings of this study. For instance, [Wei et al., \(2023\)](#) highlight how home numeracy activities strongly influence students' numeracy development, underscoring the importance of context-based resources. In line with this, it emphasizes the role of making numeracy and literacy visible through play-based and contextualized approaches, which resonates with the contextual story problems embedded in the developed e-module ([Azubuike et al., 2024](#); [Rochsun & Agustin, 2020](#)). Moodle-assisted e-modules can significantly improve students' numeracy literacy while demonstrating that digital STEAM-inquiry modules enhance literacy skills, reinforcing the effectiveness of digital instructional media ([Hidayanthi et al., 2024](#)). Similarly, the development of numeracy literacy modules within the framework of the Merdeka Curriculum aligns with the objectives of this research ([Vhalery et al., 2022](#); [Saa, 2024](#)).

From an instructional design perspective, evidence of the robustness of the ADDIE model in distance education successfully applied in developing an innovative web-based microteaching model ([Spatioti et al., 2022](#); [Widyastuti & Susiana, 2019](#)). These studies validate the methodological soundness of employing ADDIE even when adaptations such as the ADDI model are necessary due to practical constraints ([Hidayat & Nizar, 2021](#)). Furthermore, the integration of AI-enabled adaptive platforms into learning, opening pathways for the enhancement of e-modules with personalization features, synthesizes a decade of research on mathematical literacy, emphasizing both the challenges and opportunities in improving students' critical thinking and numeracy ([Strielkowski et al., 2025](#); [Khazanchi et al., 2025](#)).

Taken together, these studies strengthen the argument that the development of context-based, technology-driven e-modules through ADDIE not only addresses immediate classroom needs but also contributes to broader educational policy and innovation. Future research may therefore build upon these insights by integrating adaptive technologies, expanding subject scope, and employing comprehensive ADDIE cycles to maximize the impact on students' numeracy literacy. Innovative e-modules integrated with digital platforms continue to demonstrate strong potential in advancing students' literacy and numeracy outcomes, thus affirming the importance of sustained research in this area ([Zhang et al., 2025](#)).

CONCLUSION

This study focuses on creating e-modules for numeracy literacy that incorporate contextual story problems related to statistics, particularly in the area of data presentation, to enhance students' numeracy literacy and critical thinking abilities. The development process followed the ADDIE model, although it was completed only up to the implementation phase due to time limitations. The e-module is crafted with a well-organized structure and appealing design using the Canva application and includes contextual story problems that align with the features of the Minimum Competency Assessment (MCA).

This study indicates that the created e-module is not only valid in terms of its content and design but is also practical for use in the educational process. The approach of using contextual story problems has been shown to assist students in connecting statistical concepts to real-world scenarios, fostering the growth of critical thinking abilities and numeracy skills. Consequently, this e-module represents an innovative alternative teaching resource that effectively aligns with the implementation of the Merdeka Curriculum and supports numeracy literacy-based education. Therefore, it is advisable for educators to begin incorporating context-based digital e-modules in their mathematics teaching and to receive training in their development, ensuring that this resource can be utilized widely and effectively.

Future research should expand the development process to include the full cycle of the ADDIE model, particularly the evaluation phase, in order to obtain more comprehensive data on the effectiveness and long-term impact of the e-module. Further studies may also explore integrating interactive features such as quizzes, gamification elements, and adaptive feedback to enhance student

engagement. In addition, future research could investigate the use of context-based e-modules across different mathematical topics and educational levels to assess their broader applicability and scalability. Future studies are also encouraged to involve larger and more diverse student populations to ensure the generalizability of findings. Ultimately, these efforts will contribute to the continuous improvement of innovative digital learning resources in mathematics education.

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