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Enhancing Mathematics Learning through Problem-Based and Digital Integration: A Study on Wordwall-Based Teaching Modules

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ABSTRACT

Purpose of the study: This study aims to determine the validity and practicality of a Problem-Based Learning (PBL) module integrated with the Wordwall application for teaching the topic of similarity in junior high school mathematics.

Methodology: The research adopts the Plomp development model, which includes five systematic stages: preliminary investigation, design, realization/construction, test-evaluation-revision, and implementation. Data were collected using expert validation sheets and student practicality questionnaires to assess the quality and usability of the developed module.

Main Findings: The results show that the PBL–Wordwall-integrated module achieved a validity score of 89.83% (Very Valid) and a practicality score of 88.5% (Very Practical). The high validity demonstrates that the module's content, structure, and linguistic elements are consistent with curriculum standards and responsive to learners' cognitive levels. Likewise, the high practicality indicates that teachers and students found the module engaging, interactive, and easy to apply in classroom settings.

Novelty/Originality of this study: The novelty of this study lies in the integration of the PBL approach with digital gamification through Wordwall, creating an innovative learning environment that fosters problem-solving, critical thinking, and motivation simultaneously. Unlike traditional static modules, this design embeds real-world contextual problems within interactive digital activities, bridging pedagogical theory and technological application. This research contributes both theoretically and practically by offering a replicable model for blending inquiry-based learning with gamified platforms in mathematics education. Overall, the developed module is effective, feasible, and capable of enhancing students' engagement, conceptual mastery, and collaborative learning in mathematics.

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1. INTRODUCTION

Mathematics is a fundamental discipline that permeates every aspect of daily life, equipping individuals with the ability to think logically, reason systematically, and solve complex problems [1]-[4]. As education continues to evolve in the 21st century, it demands a shift from traditional content delivery toward pedagogical approaches that foster essential competencies such as critical thinking, creativity, collaboration, communication, and technological literacy. Accordingly, educators are expected to design learning environments that are not only enjoyable but also contextual, meaningful, and aligned with students' real-world experiences. One pedagogical model that meets these criteria is Problem-Based Learning (PBL), an approach that positions authentic, real-life problems at the center of the learning process.

Problem-Based Learning (PBL) emphasizes student-centered inquiry, where learners actively identify, explore, and analyze problems before formulating solutions collaboratively. This approach encourages independence, reflection, and higher-order thinking, leading to a deeper conceptual understanding of mathematical principles. In mathematics education, particularly within the topic of similarity (kesebangunan), the PBL approach is especially relevant. It enables students to visualize relationships between geometric figures, connect abstract concepts to concrete situations, and apply reasoning to real-world contexts. However, despite its proven pedagogical benefits, many students continue to experience difficulties in understanding the concept of similarity. Misconceptions frequently arise due to students' struggles in linking theoretical concepts with practical applications, resulting in fragmented and superficial understanding [5]-[9].

To address these issues, the development of systematic, well-structured learning modules based on PBL principles is essential. The PBL syntax—comprising stages such as student orientation to the problem, organizing learning activities, guiding investigation, developing and presenting solutions, and evaluating the learning process—provides a framework that nurtures collaboration, exploration, and reflective thinking. Each stage is designed to encourage students to engage in meaningful inquiry, communicate their reasoning, and evaluate their own learning progress. Nevertheless, in practice, teachers often face challenges in implementing PBL effectively, including the lack of appropriate instructional materials, insufficient time for structured investigations, and low student motivation during problem-solving activities.

In response to these challenges, the integration of digital learning technologies into PBL has emerged as a promising innovation for enhancing engagement and comprehension. One notable platform that supports interactive and gamified learning is Wordwall, a digital tool that enables teachers to design various engaging activities such as quizzes, matching exercises, and crosswords. The use of Wordwall in mathematics learning has been shown to increase student participation, motivation, and achievement by transforming traditional exercises into interactive experiences [10]-[13]. Its gamification features provide immediate feedback, encourage competition and collaboration, and create a more enjoyable learning atmosphere—all of which are key to sustaining students' interest in mathematics.

Despite growing research on both PBL and digital learning tools, studies that systematically integrate these two approaches—particularly in the context of mathematics learning on the topic of similarity—remain scarce. Previous research has generally focused on the application of PBL to enhance problem-solving and critical thinking skills using conventional materials such as printed worksheets [14]-[18]. These studies have not fully explored the potential of combining PBL with digital, interactive, and gamified environments that can optimize students' learning engagement and conceptual understanding. Similarly, while Wordwall has gained attention as a digital learning medium, its pedagogical integration into structured learning models like PBL has not been widely examined. Existing studies on digital learning tools tend to emphasize the use of ICT or online media in general, without developing or validating context-specific instructional modules that align with curriculum goals and 21st-century skill development. This lack of integrated research highlights a critical gap in the field of mathematics education—namely, the absence of empirically validated instructional materials that combine PBL with gamified digital tools to improve both the cognitive (conceptual understanding) and affective (motivation and engagement) aspects of learning [19]-[22]. Addressing this gap is essential for developing learning resources that are pedagogically sound, technologically relevant, and adaptable to students' needs in modern classrooms.

Therefore, this study aims to develop, validate, and evaluate the practicality of a Problem-Based Learning (PBL) module integrated with Wordwall on the topic of similarity for junior high school students. The research adopts the Plomp development model, which includes five systematic stages—investigation, design, construction, testing, and implementation. The expected outcomes of this study are twofold: (1) the developed module demonstrates high validity, indicating that its content, structure, and learning activities align with PBL principles and learning objectives; and (2) the module shows high practicality, reflecting ease of use, engagement, and effectiveness from both teacher and student perspectives. By merging PBL pedagogy with interactive digital media, this study contributes to the advancement of technology-integrated mathematics education. It provides a research-based framework for designing innovative, student-centered learning modules that not only strengthen students' conceptual understanding but also enhance their motivation and enjoyment in learning mathematics. Ultimately, this research seeks to bridge the gap between traditional and digital pedagogies, offering a meaningful step toward the realization of dynamic, inquiry-driven, and technology-supported learning environments in the 21st century.

2. RESEARCH METHOD

The development method used in this study is Plomp's model, which consists of several phases. Each phase has specific goals and steps to ensure the developed teaching module is effective and meets learning needs. Zulfikar et al., state that the Plomp Model consists of the initial investigation phase, the design phase, the realization/construction phase, the test, evaluation and revision phase, and the implementation phase [23]. The following is the Plomp Development Model in figure 1.

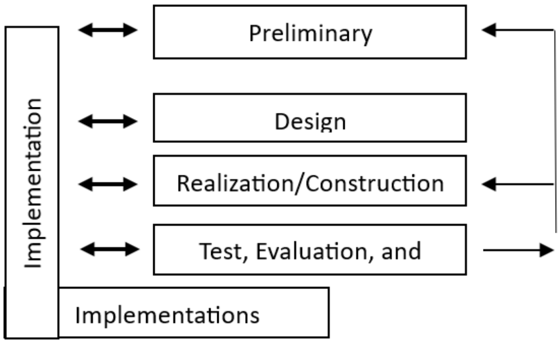

Figure 1. Plomp's Model Scheme

Data analysis techniques are used to analyze research data resulting from validation, using the average value calculation method. For the analysis criteria, a rating scale from 1 to 4 was used, namely: not good (1), quite good (2), good (3), very good (4). Here is the table of questionnaire assessment criteria in Table 1.

Table 1. Expert Validation Questionnaire Assessment Criteria Table

Score	Assessment Criteria
1	Less Valid
2	Enough Valid
3	Valid
4	Very Valid

The formula for calculating the average value is used as a calculation function to determine the final value or grade ranking of the relevant item.

$$P = \frac{\sum x}{\sum x_i} \times 100\% \quad \text{... (1)}$$

Explanation:
P = Percentage of feasibility
Σx = Sum of assessment responses
Σxi = Sum of highest responses
100 = Constant number

Based on the obtained validity results, the assessment criteria were established by looking at the validity level criteria as shown in Table 2.

Table 2. Validation Result Criteria

Percentage	Criteria
$> 0{,}80$	Very Valid
$0{,}60 \leq V < 80$	Valid
$0{,}40 \leq V < 60$	Enough Valid
$0 \leq V < 40$	Less Valid

Based on Table 2, the validation results are considered valid if the minimum score is 60 out of all the elements listed in the validation assessment checklist by media experts, content experts, and language experts. If the results are not valid, revisions or improvements will be made to analyze the data. The ideal value formula used to calculate the problem-solving ability of each student can be calculated using the following formula:

$$\in = \frac{\sum x}{n} \times 100\% \quad \text{... (2)}$$

Explanation:
∈ = Student's score
Σx = Sum of student scores
n = Number of student scores
100 = Constant number

Effectiveness Criteria: With the average student scores using classification as proposed by (Siswono, 2012), as shown in Table 3.

Table 3. Validity Criteria

Interval (100%)	Category
80 < NV ≤ 100	Very Valid
60 < NV ≤ 80	Valid
40 < NV ≤ 60	Enough Valid
20 < NV ≤ 40	Less Valid
0 < NV ≤ 20	Very Invalid

Analysis of student responses using a Likert scale ranging from 1-4 regarding the use of the Teaching Module and Student Worksheet developed during the learning process. The purpose is to determine students' perceived response to the developed teaching materials [24]. The Likert scale can be seen in Table 4.

Table 4. Likert scale questionnaire for student responses.

Score	Assessment Criteria
1	Disagree
2	Somewhat Disagree
3	Somewhat Agree
4	Agree
5	Strongly Agree

The aspects found in the student response questionnaire can be seen in Table 5.

Table 5. Aspects of the student response questionnaire

Aspects Being Evaluated	Item Number Statement
Convenience	1-5
Usefulness	6-10
Attraction	11-15

Student response questionnaires were used to assess the practicality of the Teaching Module and Student Worksheet, and the data obtained was then analyzed by calculating the percentage using the formula 3.

$$Practicality = \frac{Total\ score\ for\ each\ statement}{Total\ Responden}\ x\ 100\% \ldots (3)$$

Analysis of student responses based on the score interpretation criteria shown in table 6.

Table 6. Score Criteria

Percentage %	Category
0 - 20	Impractical
21 – 40	Less Practical
41 – 60	Quite Practical
61 – 80	Practical
81 - 100	Very Practical

3. RESULTS AND DISCUSSION

The learning materials developed in this study focus on validating student worksheets as teaching materials. The worksheet validation is done before it is tested on students. The purpose of this validation process is to obtain input and suggestions regarding the suitability of the material and the technical aspects of writing the worksheet, so that it can be ensured that the worksheet is feasible and ready to be used in learning activities. The validity of the teaching materials was obtained from expert assessments by assigning scores to each evaluated aspect. Additionally, to support the effectiveness of using worksheet in the learning process, the Wordwall application is also used as an interactive evaluation medium. Wordwall helps teachers provide fun practice questions, and makes it easier for students to complete and understand the material through its engaging and responsive features. The integration of worksheet and Wordwall is expected to improve students' overall motivation, engagement, and learning outcomes.

This development research uses the Plomp development model to produce teaching materials in the form of student worksheets. The Plomp model consists of five stages, namely: (1) preliminary investigation, (2) design, (3) realization or construction, (4) test, evaluation, and revision, and (5) implementation. Each stage is carried out systematically and purposefully to ensure that the developed worksheet meets the criteria for quality and suitability as teaching material that can be used and is effective.

Preliminary Investigation

An initial investigation was conducted to determine the needs for developing teaching modules. Curriculum analysis, analysis of student characteristics, and analysis of learning difficulties in the material to be taught. The purpose of this stage is to gather relevant information about the ideas to be taught and to identify the problems faced by teachers and students during the learning process. To ensure that the chosen model is suitable, an instrument on Problem-Based Learning was also studied.

The teaching material provided is about similarity. In this material, students are expected to understand similarity, solve related problems, and apply it in daily life. This results in difficulty in solving problems related to similarity and its interpretation. Based on this problem, the appropriate learning process must be chosen to achieve the desired outcomes. The Problem-Based Learning (PBL) model allows students to develop their thinking processes and improve their conceptual understanding. In addition to subject matter problems, there are also issues with the teaching materials used in schools.

Based on these problems, PBL-based worksheet learning methods are used to achieve learning objectives and provide students with the opportunity to develop their minds and discover material concepts. As a flexible teaching material, worksheet is considered necessary to use. Students are asked to actively participate in discussions with their groupmates and share what they have solved previously. Worksheets are very important because they encourage educators to create flexible teaching materials that can be used at any time.

Design

The design phase produces the initial design of the teaching materials product to be developed. The worksheet design that has been prepared has the following components:

1. Learning Model: Problem Based Learning (PBL)
2. Initial Competency: Identifying and understanding the properties of similarity
3. Pancasila Student Profile:
    a. Believing and fearing God Almighty and having noble character (starting learning with prayer and greetings)
    b. Working together in completing group assignments related to congruence material
    c. Being independent in completing individual assignments
    d. Thinking critically in expressing opinions during group discussions and classical learning
4. Learning Objectives (TP):
   Through the Problem Based Learning model using worksheet, students are expected to be able to identify similar triangles and then use them to solve contextual problems accurately.
5. Learning Objectives Flow (ATP):
   a. Students can identify and compare congruent flat shapes.
   b. Students can solve problems related to congruence in everyday life.

Realization/construction

At this stage, an initial instrument for the data presentation material worksheet with bar graphs has been produced as a result of applying the concepts that have been learned. The module on data presentation will begin to be developed according to the previously designed structure. At the design stage, a worksheet structure was compiled with the title and identification of the worksheet.

In carrying out the activity, students were divided into five heterogeneous groups, with each group consisting of students with high, medium, and low abilities. This group division aims to enhance cooperation and mutual assistance among students in the process of understanding concepts and solving problems. Group discussions serve as the primary means for students to communicate their understanding and collaboratively find solutions.

Figure 2. Display of the worksheet Identity Page

Tes, evaluasi and revision

The developed worksheet was then tested for validity by involving experts as validators. Validation was conducted to evaluate the content, design, and overall quality of the worksheet. The validators provided constructive feedback and recommendations to refine the worksheet and make it more suitable for use in the learning process. Based on the validation results, there are several suggestions for improvement, including refining the activity stages to make the worksheet flow clearer and more systematic. The goal is to ensure that each meeting has a consistent structure and supports the achievement of learning objectives, particularly for the topic of similarity.

Implementation

During the implementation phase, the teaching modules that had been declared valid and practical were then applied directly in the learning activities of 7th-grade students. In carrying out the activity, the students were divided into five heterogeneous groups, with each group consisting of students with high, medium, and low abilities. This group formation strategy aims to create a collaborative and supportive learning dynamic among group members.

Each group is encouraged to complete the activities in the module together through discussion and exploration. The discussion process serves as the primary means for students to express their ideas, explain their understanding of probability concepts, and formulate solutions to the problems presented. Learning takes place using the Problem Based Learning model, allowing students to actively discover the principles of probability themselves based on the experiences and problem-solving they directly encounter.

Using Wordwall at the end of the learning activity serves as a formative evaluation to measure the extent to which each student and group has mastered the concepts. Besides providing immediate feedback, Wordwall also fosters a positive competitive atmosphere in the classroom. The implementation of this strategy has proven capable of increasing learning enthusiasm and strengthening interaction among students [25]-[27].

Analysis of Trial Results

Expert Instrument Validation

In the expert instrument validation stage, the researcher will analyze the data results based on the validation scores from the expert validator assessments. This teaching module was validated by two validators, each with competencies relevant to their respective fields: a Mathematics Teacher from Junior High School Negeri 5 Seluma and a Mathematics Teacher from one of the Junior High School in Bengkulu City. The average score of the teaching module validators for material and construction validation is as follows Table 7.

Table 7. Expert Validation Results

No	Aspects Being Assessed	Validator 1	Validator 2	Average (%)	Category
1	Media	90.62%	84.37%	87.49	Very Valid
1	Language	85.0%	87.5%	86.25	Very Valid
3	Material	93.75%	92.18%	92.96	Very Valid
4	Practicality	93.3%	94.6%	93.95	Very Valid
Average Total				90.16	Very Valid

Based on the validation results conducted by experts, the percentage of the teaching module's feasibility score was 89.83%, with the criteria "Very Valid". The results of this study are supported by research from Rani and Sutiarso and Indriani et al., which stated that the validation results of the Problem Based Learning (PBL) based student worksheet showed a very suitable level of validity for use [28], [29]. This indicates that the developed module is suitable for use in learning. This teaching module implements learning using the Problem Based Learning (PBL) model. These results show that the developed teaching module is suitable for use in learning. This teaching module applies Problem Based Learning (PBL) model-based learning to the similarity material. After that, the product was tested on 5 groups of students (small groups). The results are as follows Table 8.

Table 8. Results of Student Responses in One-to-One Trial

Student Code	Assessment Aspects														
	Convenience					Usefulness					Attraction				
A1	4	4	5	5	4	3	4	4	5	4	5	4	5	5	5
A2	5	4	5	4	4	4	4	5	5	4	5	4	5	4	5
A3	4	5	4	5	4	3	4	5	4	5	5	4	4	5	5
A4	5	5	4	4	4	4	4	5	5	4	5	5	5	4	5
A5	4	5	4	5	4	4	3	4	4	4	5	4	5	5	5
Total Score	110					104					118				
Percentage	88%					83.3%					94.4%				
Overall Average	88.5%														
Criteria	Very Practical														

After obtaining practicality results by involving 5 heterogeneous groups, the overall average result was 88.5% with the category "Very Practical". This indicates that the Problem-Based Learning-Based Student Worksheet on Similarity Material developed is suitable for use. This research is also supported by Julfianto et al., who state that the practical results or attractiveness of Problem-Based Learning-based student worksheets are practical when viewed from student responses [30]. This indicates that Problem-Based Learning is very practical to use in student worksheets for junior high school learning.

The findings of this study reveal that the developed Problem-Based Learning (PBL)-based Student Worksheet on the topic of similarity possesses a very high level of validity and practicality, indicating its suitability for classroom implementation. The validation process conducted by two expert validators yielded an overall average score of 90.16%, categorized as "very valid". These findings affirm that both the content and design of the worksheet meet pedagogical and technical standards for effective instructional materials. The high validity score demonstrates that the worksheet aligns with the curriculum, reflects accurate conceptual understanding, and presents information using clear and engaging language structures. PBL-based worksheet achieved high validity levels, emphasizing the importance of systematic validation to ensure instructional reliability and clarity [31]-[33].

The integration of the Problem-Based Learning (PBL) model plays a central role in achieving these outcomes. PBL encourages active learning through authentic problem-solving, collaboration, and reflection, enabling students to develop higher-order thinking skills and conceptual understanding. Within this study, the worksheet facilitated group discussions, peer learning, and contextual application of mathematical similarity concepts, allowing students to connect theoretical knowledge with real-world contexts. PBL environments enhance critical thinking, problem-solving skills, and intrinsic motivation by positioning students as active constructors of knowledge [34]-[37]. Thus, the developed worksheet effectively supports the cognitive and affective dimensions of learning emphasized in the Merdeka Curriculum, which promotes independence, collaboration, and critical thinking as core student competencies.

In terms of practicality, the results of the one-to-one and small-group trials indicated an overall average score of 88.5%, categorized as "very practical." This suggests that students found the worksheet both engaging and useful for supporting their learning processes. The positive student responses, particularly in the aspects of *convenience*, *usefulness*, and *attractiveness*, demonstrate that the design and activities of the worksheet are appropriate for learners' cognitive levels and encourage active participation. The findings are consistent with Masdar and Lestari (2021) as well as Fitri et al. (2020), who emphasized that PBL-based worksheets foster active engagement and are perceived by students as interactive, enjoyable, and effective tools for deep learning. The group-based activities designed in this research—where students of different ability levels collaborated—also encouraged peer tutoring and social learning, fostering not only academic achievement but also interpersonal skills aligned with the Pancasila Student Profile.

Furthermore, the integration of the Wordwall application as an interactive digital assessment tool significantly contributed to enhancing student engagement and motivation during the learning process. The application provided immediate feedback, stimulated competitive yet collaborative classroom dynamics, and helped sustain students' attention through gamified exercises. Digital platforms such as Wordwall enhance formative assessment quality by providing dynamic, interactive, and responsive learning experiences [38]-[42]. The hybrid use of printed worksheet materials and digital tools demonstrates the potential of combining traditional and technology-enhanced learning strategies to promote digital literacy and active engagement among students [43]-[47].

From a broader perspective, the findings support the Plomp development model as a robust framework for producing valid and practical instructional materials. Each phase—ranging from preliminary investigation to implementation—ensured a systematic and iterative refinement process. The iterative validation and revision steps ensured that the final worksheet version addressed both pedagogical and technical concerns, resulting in a product that is not only feasible for classroom use but also aligned with the current educational reform in Indonesia emphasizing student-centered and inquiry-based learning. The overall outcomes highlight several important implications. First, the study provides empirical evidence that PBL-based worksheet development significantly enhances the quality of mathematics learning materials, making them more contextual and student-oriented. Second, the integration of digital formative assessment tools like Wordwall demonstrates a practical pathway for schools to incorporate technology in everyday learning without requiring high infrastructure costs. Finally, the research supports the notion that systematic instructional design, grounded in development models such as Plomp, can serve as a replicable model for educators aiming to produce effective teaching materials across various subjects.

The novelty of this research lies in its innovative combination of the Problem-Based Learning model with the interactive digital platform Wordwall using the Plomp development framework. Unlike prior studies that only developed static PBL materials, this research presents an interactive learning module that merges pedagogical design with gamification to improve student engagement and understanding. Furthermore, this study does not stop at the development stage but proceeds to empirically test the module's validity and practicality through expert evaluations and student feedback. The dual focus on pedagogical soundness and technological usability provides a comprehensive contribution to the field of mathematics education. This approach introduces a new model for developing teaching materials that are not only conceptually robust but also engaging, easy to use, and aligned with the digital learning culture of today's students. The results of this study have several important implications for education. For teachers, the developed module offers a ready-to-use teaching tool that integrates PBL strategies with digital interactivity, making mathematics lessons more engaging and effective. For students, the use of Wordwall fosters active participation, collaboration, and motivation by turning learning activities into enjoyable challenges. For curriculum developers, the study emphasizes the need to embed digital gamification and inquiry-based learning principles within instructional materials to meet the competencies of 21st-century learners. In addition, the findings provide valuable insights for educational researchers to further explore the synergy between pedagogical innovation and technology integration in mathematics instruction. By successfully combining PBL with a gamified digital platform, this study supports the transformation of mathematics learning into an interactive, student-centered, and technology-enriched experience.

Despite the promising findings, this study has several limitations that need to be addressed in future research. First, the research was limited to testing the validity and practicality of the developed module without measuring its effectiveness in improving students' learning outcomes quantitatively. Second, the number of participants involved in the practicality testing was relatively small, which may limit the generalizability of the results. Third, the implementation was conducted only on one mathematical topic—similarity—so the module's applicability to other topics remains to be explored. Additionally, the study did not include teacher perspectives or longitudinal observations, which could provide deeper insights into the long-term use and sustainability of the module. These limitations open opportunities for further development and replication in broader educational contexts. Based on the findings and identified limitations, several recommendations are proposed for future research and educational practice. Future studies should focus on evaluating the effectiveness of the PBL-Wordwall module in enhancing students' problem-solving abilities, motivation, and conceptual understanding through experimental or mixed-method approaches. The module should also be adapted and tested on other mathematics topics, such as geometry, algebra, or statistics, to determine its broader applicability. Collaboration between researchers and classroom teachers is strongly recommended to ensure that the module design reflects classroom realities and supports long-term integration into teaching practices. Moreover, integrating the module with other digital learning tools such as GeoGebra, Kahoot, or Quizizz could further enhance its interactivity and appeal. Educational policymakers are also encouraged to promote digital-based PBL modules as part of professional development initiatives to equip teachers with effective strategies for integrating technology into mathematics education.

4. CONCLUSION

This study concludes that the developed Problem-Based Learning (PBL) module integrated with Wordwall is both valid and practical for enhancing the teaching and learning of the topic of similarity in junior high school mathematics. The expert validation results indicated a very high validity level with a total score of 89.83%, while the student practicality test showed a very practical category with a score of 88.5%. These findings demonstrate that the module effectively integrates content, language, and media components in alignment with students' cognitive development and curriculum objectives. The incorporation of Wordwall as a digital gamification platform enhances the module's interactivity, engagement, and accessibility, creating a dynamic learning environment where students can explore concepts collaboratively, develop problem-solving skills, and sustain motivation throughout the learning process. The implications of this research emphasize the potential of combining problem-based learning with digital gamification tools to foster active and meaningful learning experiences in mathematics. The module not only supports cognitive skill development but also promotes critical thinking, communication, and collaboration—skills essential for 21st-century learning. Teachers can utilize this integrated approach to make abstract mathematical concepts more concrete and contextually relevant, while students benefit from increased autonomy and enjoyment in learning. Furthermore, this study highlights the need for schools to invest in digital pedagogical innovations that balance academic rigor with engaging learning experiences. The developed module thus serves as a model for future curriculum design and can be adapted to various mathematical topics, supporting a more interactive, student-centered, and technology-enriched approach to mathematics education.

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