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E-flipbook innovation through problem-based learning: Enhancing mathematical concept mastery

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ABSTRACT

Background: Mathematical conceptual understanding remains a key issue in junior high school education. Innovation in learning media, such as digital tools, is needed to support effective learning. One promising approach is integrating Problem-Based Learning (PBL) with interactive digital media like E-flipbooks to enhance students' engagement and comprehension in mathematics.

Aim: This study aimed to develop a Problem-Based Learning-based E-flipbook that is valid, practical, and effective in improving students' mathematical concept understanding.

Method: This research employed a Research and Development (R&D) design utilizing the ADDIE development model. The study participants were seventh-grade students from one of the public junior high schools located in the Batanghari Nuban sub-district during the 2024/2025 academic year. Data were collected through interviews, questionnaires, and mathematical concept comprehension tests. Data analysis involved expert validation, practicality indices, a proportion test, and a t-test.

Results: The e-flipbook received high validity ratings from material experts (0.87) and media experts (0.90). Teacher and student responses indicated high practicality, with indices of 0.81 and 0.86, respectively. Additionally, over 60% of students demonstrated good understanding of mathematical concepts. The N-Gain and hypothesis test results showed a significant improvement in the experimental group compared to the control group.

Conclusion: The e-flipbook developed through the problem-based learning approach was proven to be valid based on expert judgment, practical according to user responses, and effective in enhancing students' mathematical concept understanding. These findings indicate that the integration of digital media and problem-based strategies can meaningfully support student learning. The product serves not only as a teaching aid but also as a tool to foster student engagement and active problem-solving. Therefore, this e-flipbook has the potential to be adopted as an innovative instructional resource in mathematics classrooms.

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INTRODUCTION

Mathematics is widely recognized as a fundamental discipline that underpins various fields of science and technology. It plays a crucial role not only in academic development but also in fostering logical thinking, analytical skills, and problem-solving abilities—core competencies in the 21st century. In an era marked by rapid technological change and global challenges, mathematics equips individuals with essential tools to interpret data, make informed decisions, and engage in critical reasoning. Thus, mathematics education serves as a cornerstone in preparing students to meet modern societal demands. As noted by Nengsi et al. (2025), mathematics is interconnected with other disciplines and must be effectively mastered by students to ensure success across academic and real-life contexts. Accordingly, more emphasis must be placed on how students understand mathematical content rather than just its presence in the curriculum.

To solve mathematical problems effectively, students need a solid grasp of the underlying concepts and rules. Nurhaliza et al. (2025) emphasized that conceptual understanding is the foundation for students to answer mathematical questions and apply their knowledge in real-world contexts. Mastery of concepts should therefore be a primary instructional goal. Unfortunately, the reality in Indonesia suggests that many students still struggle in this area. The Programme for International Student Assessment (PISA) in 2018 reported an average mathematics score of 379 for Indonesian students—well

below the OECD average—placing the country 73rd globally (Usman, Jamaan, Arnellis, Permana, & Zafirah, 2025).

Classroom-level findings further support this concern. A preliminary study conducted by the researcher at one of the public junior high schools in the Batanghari Nuban sub-district revealed a striking pattern: only 5 out of 25 seventh-grade students were able to fully and accurately solve the diagnostic mathematics problems given. Most students demonstrated a lack of conceptual understanding, particularly in connecting mathematical ideas and applying them to problem-solving situations. Their responses often reflected procedural memorization rather than meaningful comprehension, indicating a surface-level engagement with the material. This condition reflects a broader challenge faced in mathematics classrooms, where traditional instruction methods may fail to build deep understanding. Without immediate intervention, this learning gap could widen over time and hinder students' ability to grasp more complex mathematical topics in the future. These findings highlight an urgent need to implement more effective instructional strategies that not only deliver content but also promote deep mathematical thinking and conceptual mastery.

One promising instructional approach is the application of the Problem-Based Learning (PBL) model. Afridiani et al. (2020) suggested that PBL engages students actively and helps them construct knowledge through meaningful learning experiences. Real-world problems presented in PBL become the basis for investigation and exploration (Albab, Wanabuliandari, & Sumaji, 2021). As Ikarihayati et al. (2023) noted, PBL supports student-centered learning and enhances problem-solving and critical thinking skills. It has been found to be more effective than traditional models in improving conceptual understanding (Afridiani et al., 2020).

Equally important is the role of instructional media. Insights from interviews with a mathematics teacher at the same school revealed that classroom activities relied heavily on textbooks, with minimal use of digital media. Teaching remained teacher-centered and formula-driven, resulting in student passivity and disengagement. To address this, educators must adopt learning tools that incorporate technology and are better aligned with students' learning preferences and today's digital landscape.

Modern educational practices increasingly rely on technology to enhance accessibility and engagement (Aisyah, Lusiana, & Retta, 2025). Rustam et al. (2024) stressed that integrating technology into instruction is now essential for educators. Mumpuni et al. (2023) pointed to platforms like K-Visoft Flipbook Maker as effective tools for developing digital modules. These can be designed to align with the PBL model and support real-life, contextual learning.

Among these digital innovations, e-flipbooks have gained popularity for their ability to merge interactive elements such as text, animation, and images into a user-friendly format. This makes classroom activities more engaging and supports deeper comprehension (Ismail, Sinaga, & Sriadhi, 2022). According to Prihastuti et al. (2024), the interactive page-turning design of flipbooks mimics real books, offering a more dynamic learning experience. Research by Faizah et al. (2023) confirmed that e-flipbooks are both valid and feasible for classroom use, showing positive effects on student engagement and learning outcomes.

Despite their potential, most existing studies tend to explore PBL and e-flipbooks as independent interventions. There is still limited empirical evidence on how integrating these two strategies can effectively enhance students' conceptual understanding in mathematics. Moreover, while previous research often focuses on general learning outcomes or student motivation, few emphasize conceptual mastery—a critical foundation for mathematical reasoning and application. In response to this gap, the present study aims to develop an e-flipbook integrated with Problem-Based Learning to improve students' mathematical conceptual understanding. This innovation is expected to align with technological trends while addressing the instructional needs of today's learners.

METHOD

This study employed a Research and Development (R&D) approach aimed at producing a digital instructional product in the form of an E-flipbook integrated with the Problem-Based Learning (PBL) model to enhance students' conceptual understanding in mathematics. The instructional development process in this study was guided by the ADDIE model, which outlines a systematic sequence of five phases for designing effective learning products. The stages of this model are presented in Figure 1.

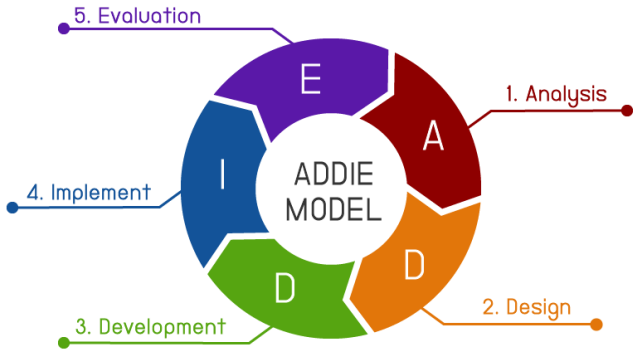

Figure 1. ADDIE Model

The ADDIE model includes five structured phases: Analyze, Design, Development, Implementation, and Evaluation. In this study, the analysis phase involved identifying student needs and learning objectives. The design phase focused on planning the layout and structure of the E-flipbook. During the development phase, the media was created using Flipbook Maker and validated by content and media experts. The implementation phase was carried out in the experimental classroom, followed by an evaluation phase that involved assessing the product's practicality and effectiveness based on student learning outcomes.

The study was carried out during the second semester of the 2024/2025 academic year at a public junior high school located in the Batanghari Nuban sub-district. The participants were selected through cluster random sampling. A Pretest-Posttest Control Group Design was used to compare the learning outcomes between the experimental and control groups. The sample consisted of two seventh-grade classes: the experimental group with 20 students and the control group with 19 students. To measure conceptual understanding, a test consisting of five open-ended questions was developed and validated by subject matter experts. This instrument was administered as both a pretest and posttest.

For data analysis, the researchers applied an independent samples t-test to determine whether there was a statistically significant difference in students' posttest scores between the two groups. Prior to conducting the t-test, normality and homogeneity tests were performed to ensure that the data met the assumptions for parametric testing. The t-test results served as the basis for evaluating the effectiveness of the PBL-based E-flipbook in enhancing students' conceptual understanding of mathematical concepts.

RESULTS AND DISCUSSION

Analysis

The analysis phase encompassed three major components: analysis of learners' characteristics, needs analysis, and curriculum analysis.

First, an analysis of students' characteristics was conducted to identify their learning abilities, skill levels, and conceptual understanding in mathematics. A preliminary test involving 25 seventh-grade students was administered on November 13, 2023. The results indicated that most students demonstrated a low level of conceptual understanding in mathematics. Errors were frequently observed in procedural operations, particularly in substitution steps and in calculating area-related problems.

These findings highlight the urgent need for appropriate learning tools to improve students' conceptual understanding in mathematics.

According to Dick and Carey (2009), analyzing learners' characteristics is a crucial step in instructional design as it ensures that the developed materials are aligned with students' cognitive abilities, learning styles, and prior knowledge, which in turn supports the achievement of instructional objectives. Similarly, Branch (2009) emphasizes that understanding the target audience is foundational in the systematic design of instruction, as it directly influences content decisions, instructional strategies, and media selection.

Second, a needs analysis was conducted to identify both students' and teachers' instructional needs and challenges in the classroom. This activity took place on the same date in a seventh-grade class at a public junior high school in the Batanghari Nuban sub-district. Based on an interview with the mathematics teacher, it was revealed that the primary instructional resource used was a printed textbook, and that digital technology had not yet been utilized to support classroom instruction. Moreover, the teaching approach remained teacher-centered, with limited student engagement. As a result of the discussion and consultation with the teacher, the development of an E-flipbook integrated with the Problem-Based Learning (PBL) model was proposed and subsequently approved for classroom use.

Third, a curriculum analysis was conducted to ensure that the learning objectives and targeted competencies align with national curriculum standards. The school adopted the Kurikulum Merdeka (Independent Curriculum), under which the topic selected for this study was algebraic expressions for seventh-grade students. The objective of this analysis was to ensure that the E-flipbook media being developed would align with the expected learning outcomes set by the curriculum. The proposed E-flipbook integrating PBL for the topic of algebraic expressions was submitted to the mathematics teacher and received approval for development and classroom implementation.

Before proceeding to the next phase, a preliminary evaluation was conducted to assess whether the findings from the analysis stage could inform the development of a feasible, relevant, and effective instructional product. This step was essential in ensuring that the E-flipbook being developed would be suitable for addressing students' current conceptual understanding levels and classroom needs.

Design

The design phase played a critical role in constructing the pedagogical and visual structure of the E-flipbook, ensuring that it aligned with the core principles of Problem-Based Learning (PBL). At this stage, the researchers began by outlining the essential instructional components, including the introduction, learning objectives, contextual problem presentations, content explanation, student activities, and reflective prompts. The instructional flow was designed to support students' learning progression from initial problem orientation to solution development and final reflection. This systematic arrangement aimed to provide a coherent learning experience that guided students through each step of conceptual exploration (Hmelo-Silver, 2004; Barrows, 1996).

Visual and technical aspects of the E-flipbook were also carefully planned to optimize engagement and usability. Design choices such as page size, background color, font type and size, heading structure, and the placement of mathematical symbols were made with attention to readability and aesthetic appeal. The design included interactive visuals and simple animations to help visualize complex mathematical ideas, particularly in the topic of algebraic expressions. Color schemes and symbols were chosen to be both age-appropriate and content-relevant, enhancing both attention and retention during use (Mayer, 2009; Clark & Mayer, 2016).

In addition to layout and structure, careful attention was given to the selection and organization of content resources. Real-world problem scenarios, relevant to students' everyday experiences, were embedded throughout the E-flipbook to serve as stimuli for inquiry. These problems were selected based on their ability to foster conceptual understanding and encourage critical thinking in line with the PBL

approach. Supporting resources—including instructional texts, exercises, and formative assessments—were compiled from validated educational sources. These components were integrated to create a comprehensive learning medium that not only presented mathematical content but also promoted independent exploration and reflective learning (Jonassen, 1999; Branch, 2009).

Development

During the development phase, the instructional product consisting of the e-flipbook and its accompanying student worksheets was systematically produced based on the finalized outputs of the preceding design phase. The e-flipbook was developed using canva, a design platform that enabled the integration of text, graphics, animations, and layout elements into a cohesive digital format. To complement the flipbook, interactive student worksheets (LKPD) were created and enhanced through the Liveworksheets website, enabling online access and submission functionality. These worksheets were linked directly within the E-flipbook, allowing seamless navigation for students from content to activity. The development interface and integration process of the E-flipbook is illustrated in Figure 2, showcasing how digital tools were employed to create an engaging and interactive learning environment.

Figure 2. Digital Display of the E-Flipbook Developed through the Flippingbook Website

As shown in Figure 4, the Flippingbook platform was utilized to convert the designed content into an interactive digital book format. This platform provided page-flipping features, hyperlink embedding, and responsive accessibility across devices. Through this, the E-flipbook became not just a static instructional resource, but a dynamic medium allowing real-time engagement with linked worksheets hosted on Liveworksheets. Once the digital product was completed, an expert validation process was carried out to ensure content quality and media functionality. This included two distinct evaluations: (1) material/content validation and (2) media/interface validation. Material validation was conducted by two experts both faculty members at Universitas Islam Negeri Raden Intan Lampung. They evaluated two primary aspects, content feasibility and presentation quality. The results are summarized in Table 1.

Table 1. Results of Material Expert Validation

Assessment Aspect	V1	V2
Content feasibility	37	36
Presentation feasibility	25	25
Validity score	62	61
Validity index	0,88	0,86
Classification	Very Valid	Very Valid

The data in Table 1 indicate that both experts classified the E-flipbook's content as very valid, with a high degree of alignment to instructional objectives and content standards. Media validation was also conducted by the same experts, focusing on visual and technical criteria including design layout, readability, and language usage. The results of this validation are shown in Table 2.

Table 2. Results of Media Expert Validation

Assessment Aspect	V1	V2
Content feasibility	30	28
Languange feasibility	25	28
Validity score	55	56
Validity index	0,88	0,91
Classification	Very Valid	Very Valid

The scores in Table 2 confirm that the media aspect of the E-flipbook was also deemed very valid, indicating strong visual and linguistic quality. Based on both sets of validation results, the PBL-based E-flipbook was considered valid and feasible for classroom implementation.

Implementation

The validation results indicating that the developed E-flipbook was deemed valid, the next step involved product trials in a small group setting. This stage aimed to assess the practicality of the E-flipbook before proceeding to a larger-scale trial.

1). Small Group Trial

The small group trial was conducted with one mathematics teacher and six students representing varying academic abilities (high, medium, and low). Both the teacher and students were given a response questionnaire after engaging in learning activities using the Problem-Based Learning (PBL)-based E-flipbook. The results of the teacher and student response questionnaires are summarized in Table 3.

Table 3. Summary of Student and Teacher Response Questionnaires

	Student Response	Teacher Response
Number of items	15	20
Total score	324	69
Maximum score	360	80
Minimum score	90	20
Practicality index	0.86	0.81
Classification	Very Practical	Very Practical

Based on Table 3, the practicality index for student and teacher responses was 0.86 and 0.81, respectively. These values fall within the "Very Practical" classification, indicating that the E-flipbook was engaging and feasible for classroom implementation.

2). Large Group Trial

After confirming the product's practicality, a large group trial was conducted to evaluate the effectiveness of the E-flipbook. This involved comparing the learning outcomes between two groups: one taught using the PBL-based E-flipbook (experimental group) and the other using traditional instructional methods without the E-flipbook (control group). The results of the pretest and posttest assessments, which measured students' conceptual understanding of algebraic expressions, are presented in Table 4.

Table 4. Students' Conceptual Understanding Scores

	Experiment		Control	
	Pre	*Post*	*Pre*	*Post*
Average	38	81	41	66
Max score	45	88	52	75
Min score	32	70	35	58

As shown in Table 4, the average posttest score in the experimental class was significantly higher (81) compared to the control class (66). Similarly, both the maximum and minimum scores in the experimental class exceeded those of the control class, indicating that the E-flipbook contributed positively to students' conceptual understanding in mathematics.

Evaluation

The final stage involved a summative evaluation aimed at comprehensively assessing both the process and the outcomes of the development. This evaluation aimed to determine the effectiveness of the Problem-Based Learning (PBL)-based E-flipbook in improving students' conceptual understanding in mathematics. The evaluation focused on analyzing students' pretest and posttest results using the normalized gain (N-Gain) score, followed by prerequisite assumption tests including normality and homogeneity assessments.

Table 5. N-Gain Results for Conceptual Understanding Test

Class	N	*N-Gain* Min	*N-Gain Max*	Average *N-Gain*
Experiment	20	0,58	1,00	0,84
Control	19	0,57	1,00	0,73

As shown in Table 5, the average N-Gain score of the experimental class was higher (0.84) compared to the control class (0.73), indicating that students in the experimental group experienced greater improvement in their conceptual understanding. To validate the suitability of the data for parametric testing, normality and homogeneity tests were carried out.

Table 6. Normality Test Results for N-Gain Data

Class	*Sig.*	*α*
Experiment	0,778	0,05
Control	0,247	0,05

Table 6 indicates that the significance values for both groups exceeded the alpha level of 0.05, leading to the acceptance of the null hypothesis. This means that the N-Gain scores were normally distributed for both groups.

Table 7. Homogeneity Test Results for N-Gain Data

Data	*Sig.*	*α*
N-gain	0,292	0,05

As presented in Table 7, the significance value was above the threshold of 0.05, indicating that the variances between the groups were statistically equal (homogeneous). Given that the N-Gain data were both normally distributed and homogeneous, a parametric test, namely the Independent Samples t-test, was employed to compare the mean N-Gain scores between the experimental and control groups.

The significance value (0.004) was less than the alpha level (0.05), leading to the rejection of the null hypothesis. This indicates a statistically significant difference in conceptual understanding improvement between students who used the E-flipbook and those who did not. Thus, it can be concluded that the PBL-based E-flipbook was effective in enhancing students' mathematical conceptual understanding.

The results of this study demonstrate that the E-flipbook based on Problem-Based Learning (PBL) was developed systematically through the ADDIE framework and successfully met the learners' needs identified during the analysis phase. The initial needs assessment and learner analysis revealed students limited conceptual understanding in mathematics and lack of exposure to digital learning tools. This aligns with the suggestion by Dick and Carey (2009) that understanding learners' characteristics and learning contexts is critical for designing effective instructional materials. The alignment of the product with students' cognitive needs provided a strong foundation for its development.

In terms of validity, expert evaluations from content and media validators yielded high scores with validity indices above 0.85, indicating that the E-flipbook was classified as “very valid.” The feedback received confirmed that both the content accuracy and media design were pedagogically sound and suitable for seventh-grade students. These findings support previous studies such as those by Branch (2009) and Daryanto (2013), which emphasized the importance of aligning instructional media with curriculum standards and learner characteristics to ensure instructional quality and relevance.

The practicality of the E-flipbook was supported by data from small group trials involving teachers and students with varying achievement levels. The practicality index reached 0.86 for students and 0.81 for teachers, categorized as "very practical." This implies that the media was not only easy to use but also engaging and relevant for classroom implementation. These results are consistent with research by Arsyad (2015), which states that practicality reflects the usability of instructional media in real learning environments.

Furthermore, the effectiveness of the E-flipbook was validated through large group trials, where a significant improvement was observed in students’ conceptual understanding. The experimental group showed a higher average posttest score compared to the control group. The N-Gain analysis revealed a score of 0.84 for the experimental group and 0.73 for the control group. A t-test further confirmed a statistically significant difference between the two groups ($p < 0.05$), suggesting that the E-flipbook effectively supported students’ learning outcomes. These findings resonate with previous research showing that digital learning tools, when integrated with active learning models like PBL, can significantly improve students' comprehension (Mayer, 2009; Hmelo-Silver, 2004).

Taken together, the development and implementation of the E-flipbook based on PBL have shown strong validity, practicality, and effectiveness. The product not only addressed the identified instructional gaps but also provided an engaging and interactive platform for learning algebraic expressions. These results provide a valuable contribution to the growing body of literature on the integration of digital media and student-centered learning models in mathematics education.

CONCLUSION

The development of an E-flipbook based on the Problem-Based Learning (PBL) model for algebraic expression material was carried out through the ADDIE model, covering analysis, design, development, implementation, and evaluation stages. The validation results from content experts showed validity indices of 0.88 and 0.86, while media experts rated it at 0.88 and 0.91, all categorized as very valid. Practicality was evaluated through small-group trials involving six students and one teacher, where the practicality index reached 0.86 for students and 0.81 for the teacher, classified as very practical. Effectiveness was confirmed through a field trial involving experimental and control classes. The experimental group showed an N-Gain average of 0.84 compared to 0.73 in the control group. Furthermore, the Independent Sample T-Test yielded a significance value of 0.004 (< 0.05), indicating a significant difference in the conceptual understanding improvement between students using the E-flipbook and those who did not.

These findings confirm that the developed E-flipbook is not only valid and practical but also effective in enhancing students' mathematical conceptual understanding. The integration of PBL within the E-flipbook format facilitated independent learning and increased student engagement with real-life problem contexts. Thus, the objectives of this study—to develop, validate, and evaluate the effectiveness of the E-flipbook—were successfully achieved. The product offers a valuable solution to traditional instruction limitations and has the potential to be further developed and implemented in broader educational contexts.

AUTHOR CONTRIBUTION

The first author was responsible for designing the study, developing the media, collecting the data, and drafting the manuscript. The second author contributed to expert validation, data analysis, academic supervision, and final editing of the manuscript.

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