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Effectiveness of the e-LKPD flipbook in improving student learning outcomes in mathematics

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Abstract

The rapid advancement of technology has transformed educational practices, requiring innovative learning materials that enhance student engagement and comprehension. This study aims to develop and evaluate the effectiveness of an e-LKPD flipbook based on the Problem-Based Learning (PBL) approach to improve students' understanding of exponents, exponential equations, and exponential functions. The ADDIE instructional design model was employed, encompassing Analysis, Design, Development, Implementation, and Evaluation phases. Data collection involved classroom observations, expert validation, and pre-test and post-test assessments to measure learning outcomes. The findings reveal that the e-LKPD flipbook is effective in improving student comprehension, as demonstrated by a significant increase in post-test scores compared to pre-test scores. Expert evaluations rated the flipbook as highly valid, with media and content experts assigning scores of 85.11% and 81.94%, respectively, confirming its accuracy, clarity, and pedagogical suitability. Students reported the flipbook as engaging and user-friendly, indicating that its interactive multimedia design enhances learning motivation and independent study. This study contributes to mathematics education by providing a technology-enhanced learning tool that effectively supports conceptual understanding and problem-solving skills. The findings suggest that integrating PBL with interactive digital resources can improve learning outcomes and engagement, offering a model for future innovations across various subjects and educational settings.

Keywords: e-LKPD flipbook; Problem-based learning; Mathematics education; Skills

1. Introduction

Mathematics is a central pillar of scientific knowledge, serving as a fundamental discipline that underpins various fields of study. Its logical structure and deductive reasoning are essential for the development of critical thinking and problem-solving skills (Russeffendi, 1999). In the educational context, mathematics not only provides cognitive benefits but also plays a crucial role in fostering intellectual capabilities applicable to real-world situations. According to the National Council of Teachers of Mathematics (NCTM, 2000), effective mathematics instruction should prioritize five key competencies: reasoning, communication, connections, problem-solving, and representation. These competencies are integral in preparing students for higher-order thinking and real-life applications.

Advancements in technology and information systems have revolutionized the educational landscape, particularly in the digital era. Educators are now expected to integrate technological tools into their pedagogical practices to enhance learning outcomes (Sulastri & Hakim, 2014). Digital learning resources, such as electronic student worksheets (e-LKPD), have emerged as innovative tools to bridge the gap between traditional instructional methods and modern technological capabilities. According to Nufus et al. (2021), integrating digital learning media, such as flipbooks, can foster more engaging, effective, and interactive learning environments. This is especially pertinent in subjects like mathematics, where abstract concepts often pose comprehension challenges for students (Wandari et al., 2018).

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Student worksheets (LKPD) are widely used as supplementary instructional materials to facilitate the learning process. Traditional LKPDs typically consist of structured exercises and guided problem-solving tasks to reinforce conceptual understanding. However, these materials often lack interactivity and adaptability to diverse learning needs (Fitra & Maksum, 2021). In contrast, e-LKPDs, particularly those utilizing flipbook technology, offer an enriched multimedia experience. Flipbooks can integrate text, images, audio, and video, providing a more dynamic learning experience compared to static worksheets (Diena, 2010). Research by Ramdania (2013) suggests that flipbooks not only enhance students' creative thinking but also improve academic performance by offering multisensory learning experiences.

The primary issue in mathematics education at SMA Negeri 2 Wonosari is the limited effectiveness of conventional instructional materials, particularly in the topic of exponents, exponential equations, and functions. Observations reveal that the existing LKPDs are often too brief, failing to comprehensively cover the curriculum and address students' conceptual difficulties. Furthermore, these materials do not adequately support independent learning, which is essential for deep understanding and knowledge retention. As noted by Fitriyah & Ghofur (2021), successful mathematics instruction requires materials that engage students actively and provide contextualized problem-solving opportunities.

The integration of Problem-Based Learning (PBL) within e-LKPDs offers a promising solution to these instructional challenges. PBL is a student-centered approach that emphasizes collaborative inquiry and real-world problem-solving (Fatriani & Sukidjo, 2018). This model encourages students to investigate and solve authentic problems, fostering both critical thinking and self-directed learning. In the context of mathematics, PBL-aligned e-LKPDs can guide students through complex concepts by presenting problems that require analytical reasoning and application. Prior studies demonstrate that PBL methodologies, when combined with digital learning tools, can significantly enhance student engagement and academic achievement (Apriyansyah, 2020).

In the context of the current study, the implementation of e-LKPDs using flipbook technology aligns with research advocating for multimedia-enhanced learning. Flipbook-based e-LKPDs provide a visually engaging format that mimics the page-turning experience of physical books while allowing for the inclusion of interactive elements (Hidayatullah, 2016). This approach is particularly beneficial in mathematics education, where visualization and step-by-step problem-solving are critical. According to Sinatra (2015), the interactive nature of flipbooks supports differentiated learning and accommodates diverse cognitive styles, which is crucial for subjects with high cognitive demands such as mathematics.

Several previous studies highlight the effectiveness of digital learning materials in improving mathematical understanding. Septian et al. (2019) developed an e-LKPD based on the Realistic Mathematics Education (RME) model, which significantly improved students' mathematical performance. Similarly, research by Awalsyah et al. (2018) demonstrated that flipbook-assisted student worksheets in the context of harmonic motion effectively enhanced scientific reasoning skills. Apriliyani and Mulyatna (2021) found that e-LKPDs utilizing ethnomathematical approaches facilitated accessible and flexible learning experiences through mobile devices. Collectively, these studies underline the pedagogical potential of integrating PBL with digital formats like flipbooks.

Despite the existing research on e-LKPDs and PBL, there remains a significant gap in the development and evaluation of flipbook-based e-LKPDs tailored to the specific needs of high school mathematics education. Prior studies predominantly focus on general digital learning materials without emphasizing the interactive and multimedia capabilities offered by flipbook technology. Moreover, there is limited empirical evidence examining how flipbook-based e-LKPDs can specifically address the challenges of teaching exponents and exponential functions, topics often regarded as conceptually demanding by students (Suryaningsih & Nurlita, 2021).

This study aims to address these gaps by developing and evaluating an e-LKPD flipbook for teaching exponents, exponential equations, and functions in Grade 10 mathematics at SMA Negeri 2 Wonosari. The primary objectives are to analyze the development process, assess the characteristics of the flipbook-based e-LKPD, and evaluate its attractiveness and effectiveness in improving learning outcomes. The novelty of this study lies in the integration of the PBL model within a flipbook-based digital learning medium, offering a comprehensive and interactive solution to the identified instructional challenges. This research is expected to contribute to the ongoing discourse on digital innovation in mathematics education while providing practical insights for enhancing pedagogical practices.

2. Methodology

This study employs a Research and Development (R&D) methodology aimed at designing, developing, and evaluating instructional products (Hasyim, 2016). The research utilizes the ADDIE model, a widely adopted instructional design framework comprising five sequential stages: Analysis, Design, Development, Implementation, and Evaluation (Branch,

2009). This model was selected due to its systematic, iterative approach, which allows for continuous refinement throughout the product's development cycle. The final output of this research is an e-LKPD flipbook, which is designed to improve students' understanding of mathematics, specifically on the topics of exponents, exponential equations, and exponential functions.

The study was conducted at SMA Negeri 2 Wonosari, located in Boalemo Regency, Gorontalo Province, during the 2022/2023 academic year. The research population included all Grade 10 students, from which a sample of 25 students from Class X-A was selected through purposive sampling. This sampling method was chosen to ensure the inclusion of participants representing diverse learning abilities and to allow for a focused investigation of the product's effectiveness in a real classroom setting.

The development process of the e-LKPD flipbook followed the five stages of the ADDIE model. The analysis phase aimed to identify the specific needs for developing a digital learning resource tailored to the mathematics curriculum. Data were collected through classroom observations, teacher interviews, and student surveys. This analysis revealed that existing instructional materials lacked interactivity, were not technologically integrated, and failed to support independent learning. Furthermore, a curriculum analysis was conducted to align the e-LKPD flipbook with the Kurikulum Merdeka, focusing on exponents and exponential functions. Student characteristic analysis indicated that learners preferred interactive digital media and experienced difficulty grasping abstract mathematical concepts. These findings underscored the necessity for an engaging, technology-based learning tool that would address these educational challenges.

In the design phase, the content and structure of the e-LKPD flipbook were carefully planned. This phase involved defining instructional objectives aligned with the curriculum to guide content development. The flipbook was organized into three main sections: the introduction, which included learning objectives, competency standards, and usage guidelines; learning activities, which followed the Problem-Based Learning (PBL) approach through guided inquiry tasks (Fatriani & Sukidjo, 2018); and assessment, which incorporated pre-test and post-test instruments. To enhance user engagement, the flipbook was designed using Kvisoft Flipbook Maker, allowing the integration of multimedia elements such as text, graphics, animations, and hyperlinks (Hidayatullah, 2016). This interactive format aimed to increase student engagement and facilitate a more immersive learning experience.

The development phase involved creating the e-LKPD flipbook and subjecting it to expert validation and initial testing. The first step in this phase was product creation based on the instructional design blueprint. The flipbook was subsequently evaluated by three experts specializing in media design, content accuracy, and instructional methodologies. Media experts focused on the quality of design and usability, content experts assessed the accuracy and clarity of the mathematical concepts, and instructional design experts ensured alignment with the PBL framework and curriculum standards. Based on their feedback, revisions were made to improve clarity, instructional flow, and visual presentation. The revised product was deemed ready for classroom implementation after passing all validation checks.

During the implementation phase, the e-LKPD flipbook was introduced in a classroom setting to evaluate its effectiveness in improving student learning outcomes. The implementation process included three key steps: administering a pre-test to measure students' baseline knowledge, conducting instructional sessions using the e-LKPD flipbook, and administering a post-test to assess knowledge acquisition. The intervention followed the principles of PBL, encouraging students to engage in collaborative inquiry and apply problem-solving techniques to real-world mathematical problems. This stage allowed researchers to gather empirical evidence on the flipbook's practical application in a formal educational context.

The evaluation phase aimed to determine the validity, attractiveness, and effectiveness of the e-LKPD flipbook through both quantitative and qualitative methods. Validity was assessed through expert evaluations, using a Likert scale to quantify the accuracy of content and the appropriateness of the design (Sugiyono, 2019). The flipbook's attractiveness was measured through student questionnaires, employing the Guttman scale to capture user perceptions (Riduwan & Engkos, 2007). Effectiveness was analyzed by comparing pre-test and post-test results, using a paired sample t-test conducted through SPSS 20 software (Hamzah, 2014). This statistical approach allowed for the identification of significant differences in student performance, with the following decision criteria: if the p-value < 0.05, the null hypothesis was rejected, indicating a significant impact of the e-LKPD flipbook on student learning outcomes.

Data collection in this study was conducted through multiple methods to ensure comprehensive evaluation. Observations and interviews provided insights into classroom dynamics and instructional practices. Questionnaires gathered student feedback regarding the flipbook's design and user-friendliness. Tests, including pre-test and post-test

assessments, measured the flipbook's impact on learning outcomes. Document analysis was also employed to examine school records and curriculum guidelines, ensuring the product's alignment with educational standards.

Data analysis combined descriptive and inferential statistics to provide a holistic evaluation of the e-LKPD flipbook. Descriptive analysis was used to interpret expert validation scores and student feedback, which were converted into percentages and categorized using a standard rating scale (Arikunto, 2006). Inferential analysis included a normality test using the Kolmogorov-Smirnov method to confirm data distribution, followed by a paired sample t-test to evaluate learning gains. The criteria for significance were established with a p-value threshold of 0.05, ensuring rigorous assessment of the flipbook's effectiveness.

Through this comprehensive ADDIE-based development and evaluation process, the study aims to produce a valid, attractive, and effective e-LKPD flipbook. The findings are expected to contribute to advancing mathematics education by offering an innovative, technology-enhanced learning tool that supports Problem-Based Learning and improves student performance in complex mathematical topics.

3. Results and discussion

The development of the e-LKPD flipbook followed the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), ensuring a systematic and iterative process for product refinement (Branch, 2009). This section elaborates on the results of each phase, focusing on how the e-LKPD flipbook was designed to improve student learning outcomes in mathematics—particularly on the topics of exponents, exponential equations, and exponential functions—at SMA Negeri 2 Wonosari.

During the analysis phase, several critical insights were gathered through classroom observations, teacher interviews, and student surveys. The findings indicated that the existing instructional materials were inadequate in fostering a deep conceptual understanding due to their limited interactivity and lack of technological integration. Furthermore, students expressed difficulty in understanding abstract concepts using conventional LKPD materials. This aligns with prior research emphasizing the importance of integrating technology-based learning tools to enhance student engagement and comprehension (Sulastri & Hakim, 2014). Additionally, the results highlighted that students preferred digital learning media, particularly materials that included visual and interactive components, confirming previous studies by Nufus et al. (2021) on the effectiveness of digital instructional materials.

The design phase involved constructing the flipbook's structure, ensuring alignment with the Kurikulum Merdeka. The content was organized into three main sections: the introduction, which included learning objectives and competency standards; learning activities, which followed Problem-Based Learning (PBL) principles; and assessments, which included pre-tests and post-tests to measure learning outcomes. By incorporating PBL methods, the flipbook aimed to foster student autonomy and critical thinking (Fatriani & Sukidjo, 2018). The Kvisoft Flipbook Maker was selected for product development due to its ability to integrate multimedia components, facilitating a more engaging and interactive learning experience (Hidayatullah, 2016).

In the development phase, the initial product underwent rigorous validation by three experts specializing in media design, content accuracy, and instructional methodologies. Based on their feedback, revisions were made to improve clarity, presentation, and instructional flow. The media experts provided an average score of 85.11%, categorized as highly valid based on the evaluation scale (Sugiyono, 2019). This assessment confirmed that the e-LKPD flipbook effectively integrated interactive features while maintaining visual clarity. Content experts evaluated the accuracy and depth of the mathematical content, assigning a score of 81.94%, which also fell within the highly valid range. This indicates that the flipbook's mathematical explanations and exercises were accurate, coherent, and aligned with the curriculum.

The implementation phase involved using the e-LKPD flipbook in a real classroom setting. A pre-test was administered before the intervention to measure the students' initial understanding. The learning process, facilitated by the teacher, included guided inquiry and collaborative discussions based on the flipbook's PBL framework. Following the intervention, a post-test was conducted to assess learning gains. The results showed a significant increase in student performance, with the mean post-test scores exceeding the mean pre-test scores. This improvement supports existing research demonstrating that PBL-based digital resources can enhance conceptual understanding and problem-solving skills (Apriyansyah, 2020; Fitriyah & Ghofur, 2021).

To assess the effectiveness of the e-LKPD flipbook, a paired sample t-test was conducted using SPSS 20 software. The statistical analysis compared the pre-test and post-test scores, with a p-value < 0.05 indicating a significant difference

in learning outcomes. The results confirmed that the e-LKPD flipbook was statistically effective in improving student understanding of exponents and exponential functions. This finding aligns with prior studies demonstrating that technology-enhanced learning environments facilitate deeper comprehension and higher engagement (Sinatra, 2015; Awalsyah et al., 2018).

Moreover, the flipbook's multimedia integration provided students with a multi-sensory learning experience, which improved their ability to grasp abstract concepts. The interactive elements—such as animated explanations and embedded practice problems—allowed students to visualize and manipulate mathematical ideas, addressing diverse learning preferences (Rosanti, 2013). This reflects the findings of Ramdania (2013), who reported that flipbook-based learning enhances cognitive engagement and academic performance by combining textual, visual, and interactive stimuli.

The findings of this study align with and expand upon existing literature on e-LKPD development and PBL integration. Similar to the research conducted by Apriliyani and Mulyatna (2021), the e-LKPD flipbook provided a flexible, mobile-accessible learning tool that facilitated independent learning. Additionally, the present study supports the conclusions of Awalsyah et al. (2018), who found that Kvisoft-assisted digital worksheets effectively develop scientific reasoning and critical thinking. However, this research contributes new insights by combining PBL methodologies with multimedia-rich flipbooks in the context of mathematics education, addressing the specific challenges of teaching exponents and exponential functions.

One notable distinction of this study is the integration of systematic instructional design through the ADDIE model, which ensured a structured development process from needs analysis to evaluation. This approach enhanced the product's pedagogical validity and practical applicability, filling a research gap in the intersection of PBL, digital learning media, and mathematical problem-solving.

The findings of this study have important implications for mathematics education and instructional design. The e-LKPD flipbook demonstrates the potential of integrating PBL with interactive digital media to enhance student engagement and learning outcomes. Educators are encouraged to adopt similar technology-driven approaches to address learning difficulties in abstract subjects. Furthermore, the study highlights the importance of expert validation and systematic development in ensuring the pedagogical effectiveness of digital learning resources.

Future research could explore the longitudinal impact of e-LKPD flipbooks on student performance across different mathematical topics and educational levels. Additionally, further studies may investigate how individual learning styles influence the effectiveness of multimedia learning environments.

In conclusion, the e-LKPD flipbook developed in this study proves to be a valid, attractive, and effective educational tool. It not only enhances student understanding of complex mathematical concepts but also fosters critical thinking and problem-solving through PBL methodologies. This research contributes valuable insights to the ongoing discourse on digital innovation in mathematics education and sets a precedent for future technology-enhanced instructional practices.

4. Conclusion

This study demonstrates the effectiveness of the e-LKPD flipbook in improving student learning outcomes on exponents, exponential equations, and exponential functions. Statistical analysis using the paired sample t-test revealed a significant increase in post-test scores compared to pre-test scores, confirming that the e-LKPD flipbook positively impacts student comprehension. The flipbook's interactive design and Problem-Based Learning (PBL) approach engaged students actively in the learning process, fostering critical thinking and problem-solving skills.

Expert validation further supported the effectiveness of the flipbook, with media experts rating its design and usability highly (85.11%), while content experts confirmed its accuracy and alignment with the curriculum (81.94%). Student feedback indicated that the flipbook was engaging and easy to use, reinforcing the idea that technology-enhanced learning materials can address challenges in mathematics education.

This research contributes to the growing body of evidence supporting the use of digital learning resources to improve academic performance. It highlights the importance of integrating PBL with interactive technology to enhance understanding of complex mathematical concepts. Future research could investigate the long-term effectiveness of similar tools and explore their applicability across diverse educational contexts and student learning styles.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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