Ceddi Journal of Education
Vol. 4 No. 2 December (2025)
https://doi.org/10.56134/cje.v4i2.156

ISSN: 2830-0017 (print)
ISSN: 2830-0025 (online)

Web-Based Educational Game Development to Improve Elementary School Students' Learning Efficiency and Interest

Asri[1*], Fitriyani[2], Katie[3], Akbar Iskandar[4]

[1]*Institut Teknologi dan Bisnis Nobel Indonesia, Makassar, Indonesia*
[2]*Informatics, Universitas Teknologi Akba Makassar, Makassar, Indonesia*
[3]*Computer Science, Keele University, Staffordshire, United Kingdom*
[2]*Information Technology Education, Universitas Teknologi Akba Makassar, Makassar, Indonesia*

Abstract

The development of digital technology has encouraged the use of interactive learning media in elementary education. However, various digital innovations have not fully demonstrated a consistent pedagogical impact on student learning efficiency and interest, especially when media development emphasizes technical aspects rather than instructional design and outcome-based evaluation. This study aims to develop and evaluate a web-based educational game designed to improve elementary school students' learning efficiency and interest. The study used a design and development research approach, which included needs analysis, design, development, and evaluation stages. The research subjects consisted of 32 fourth-grade elementary school students. Data were collected through learning outcome tests (pre-test and post-test), task completion time measurements, learning interest questionnaires, and classroom observations. Quantitative analysis using a paired-sample t-test showed a significant increase in student learning outcomes after using the educational game ($t(31) = 9.27$; $p < 0.001$; $d = 1.64$) and a significant decrease in task completion time ($t(31) = 8.11$; $p < 0.001$; $d = 1.43$). Students' learning interest scores were in the high category ($M = 4.21$). These findings indicate that pedagogically designed web-based educational games are capable of simultaneously increasing the efficiency and learning interest of elementary school students.

Keywords: Educational Games; Web-Based Learning; Learning Efficiency; Learning Interest; Elementary School

Received: 20 May 2025 Revised: 9 July 2025 Accepted: 16 November 2025

Introduction

The digital transformation in elementary education has changed the way schools view the role of technology in learning. Technology is no longer positioned merely as an administrative tool or visualization of materials, but rather as an integral part of learning strategies expected to improve the quality of learning processes and outcomes. However, various studies show that the use of educational technology does not automatically result in improved learning outcomes unless accompanied by sound instructional design and measurable evaluation based on learning outcomes.

At the elementary school level, the main challenge in learning is not only delivering material but also maintaining sustained student engagement. Learning efficiency and learning interest are two key dimensions closely related to each other. Learning efficiency refers to students' ability to achieve learning objectives with optimal use of time and cognitive effort, while learning interest represents affective engagement that influences students' attention, motivation, and persistence throughout the learning process (Sari & Usman, 2019).

Low interest in learning often directly affects learning efficiency (Smarandache et al., 2022). Students who are not interested in the material tend to take longer to grasp the same concepts, experience cognitive fatigue more quickly, and demonstrate limited engagement. This condition is often found in elementary school mathematics lessons, which are often perceived as abstract, challenging, and less relevant to students' everyday experiences.

Numerous studies have shown that conventional, one-way, minimally interactive learning approaches are inadequate for meeting the learning needs of elementary school-aged students. At this stage of development, students require concrete, visual, and interactive learning experiences to develop meaningful conceptual understanding. Therefore,

*Corresponding author.
Email address: asr.asri897@gmail.com (Asri)

innovative learning media that integrate cognitive and affective aspects are becoming increasingly relevant for development.

Digital-based educational games are emerging as a promising pedagogical approach in elementary education. By integrating learning content into game mechanics such as challenges, scoring, and immediate feedback, educational games can create a more engaging learning environment and encourage active student engagement. Recent studies have shown that digital game-based learning can improve students' conceptual understanding, motivation, and positive attitudes toward learning, particularly in mathematics and science (Behnamnia et al., 2024; Wang et al., 2022).

However, the effectiveness of educational games depends heavily on the quality of the instructional design and the alignment between game elements and learning objectives. Games developed without a strong pedagogical foundation risk becoming merely a form of entertainment, with little impact on learning outcomes. Furthermore, most research on educational game development still focuses on technical aspects and usability, while empirical studies linking educational game use with learning efficiency as a quantitative outcome are relatively limited. Web-based educational games have additional advantages over platform-based applications. High accessibility, cross-device compatibility, and the absence of the need for special application installation make web-based games easier to implement in school environments with limited technological infrastructure. However, these technical advantages need to be balanced with adequate pedagogical evaluation to ensure scientifically sound learning outcomes.

Based on these conditions, this study aims to develop and evaluate a web-based educational game to improve the efficiency and learning engagement of elementary school students. This study provides theoretical contributions by clarifying the relationship between game mechanics and two key dimensions of learning, and methodological contributions through the application of a design-and-development research approach that links design decisions to measurable learning outcomes.

Method

This research uses a design and development research (DDR) approach, which aims to produce learning products while simultaneously evaluating their impact in real-world learning contexts. The DDR approach was chosen because it allows for the systematic integration of field needs analysis, learning media design, and empirical data-based evaluation (McKenney & Reeves, 2018; Richey & Klein, 2014). The study was conducted at a public elementary school in Maros Regency, Indonesia. The subjects were 32 fourth-grade students aged 9–10 years. The sampling technique used was total sampling, as all students in the class were included as participants. The class teacher acted as both a learning facilitator and a context observer during the implementation of the educational game.

The product developed is a web-based educational game for fourth-grade mathematics, adapted to the national curriculum. The game design takes into account the cognitive developmental characteristics of elementary school students by emphasizing simple visual displays, direct interaction, and immediate feedback, as recommended in research on game-based learning for elementary education (Karakoç et al., 2022; Zhang & Yu, 2022). The research instruments included a learning outcome test, a measure of task completion time, a learning interest questionnaire, and a classroom observation sheet. The learning outcome test was administered as a pre- and post-test, consisting of 20 multiple-choice questions with equal difficulty levels. The learning interest questionnaire used a five-point Likert scale to measure aspects of attention, enjoyment, and willingness to continue learning (Likert, 1932). The instrument's content validity was assessed through expert judgment, while the questionnaire's internal reliability was analyzed using Cronbach's alpha coefficient, which showed high consistency ($\alpha = 0.87$), in accordance with the reliability criteria recommended in educational research (Ahmad et al., 2024; Izah et al., 2023).

The research procedure was carried out in three learning sessions. The first session involved conventional learning, administering a pre-test, and recording task completion times as baseline data. The second session used a web-based educational game as the primary learning medium. The third session included administering a post-test and completing a learning interest questionnaire. Quantitative data were analyzed using descriptive statistics and a paired-sample t-test to examine differences in learning outcomes before and after the intervention, with a significance level of 0.05. The strength of the intervention's influence was calculated using Cohen's d effect size to provide a substantive interpretation of the analysis results (Cheung & Tai, 2023).

Results and Discussion

Result

This section presents objective research results based on quantitative analysis and observational findings following the implementation of a web-based educational game in fourth-grade elementary school mathematics. The presentation of results focuses on two main indicators: learning efficiency and student interest in learning. This approach provides a comprehensive overview of the impact of educational game use, both on cognitive achievement and on the quality of the learning process in the classroom. As initial context, the research results begin with a description of the implementation of a web-based educational game in a real-life learning situation. This presentation aims to demonstrate how the developed media is used by students and teachers, as well as how the interface design and system interaction flow support student engagement and learning efficiency. The explanation of the implementation is not intended as a technical description, but rather as an empirical basis for understanding the quantitative results presented in the following section.

Implementation of Web-Based Educational Games

The implementation of the web-based educational game was conducted directly in the school environment to ensure the system could be used optimally in an authentic learning context. During the learning process, students used the game as the primary medium for completing interactive math quizzes, while the teacher acted as a facilitator, directing learning activities and monitoring student progress. This approach enabled evaluation of system usability not only based on user perceptions but also through observations of student learning behavior while interacting with the media. The initial system interface, shown in **Figure 1**, was designed to provide a brief orientation for users before entering the core learning activities. The simple and consistent visual design aimed to reduce students' initial cognitive load and create a positive first impression of game-based learning.

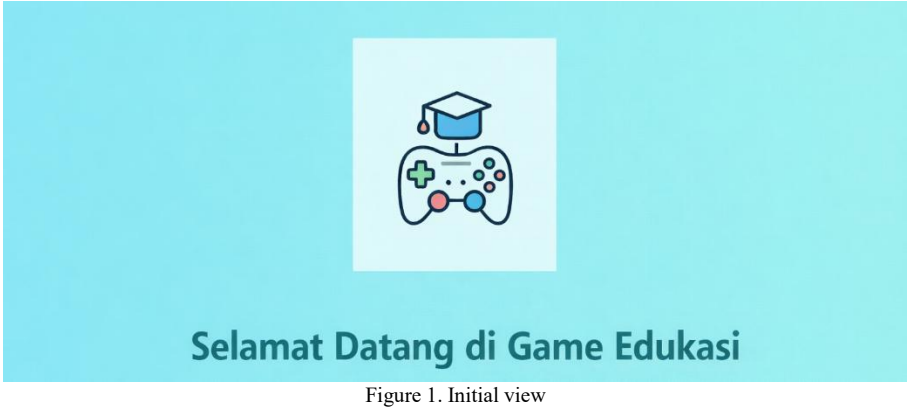

Figure 1. Initial view

Figure 1 shows the initial splash screen of a web-based educational game that serves as user orientation before entering learning activities. **Figure 2** then displays the system access path for user authentication, allowing individual student identification. This mechanism ensures that each student's learning activities and outcomes are accurately recorded, supporting ongoing monitoring of learning progress.

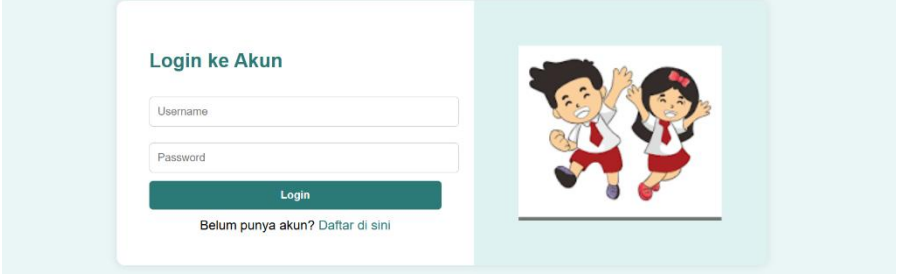

Figure 2. Authentication page

After successfully logging into the system, students are directed to the main page, which serves as a navigation center for learning activities. This page displays a menu of materials, quizzes, and learning outcomes in the form of easily recognizable icons. The intuitive navigation structure is designed to minimize the time students spend understanding the system flow, allowing for more efficient use of learning time. **Figure 3** shows the main page, which serves as the navigation center for student learning activities.

Figure 3. Main page

The system's core feature is an interactive quiz menu that presents math problems aligned with basic elementary school competencies. Quizzes provide immediate feedback, allowing students to identify errors and independently correct their understanding. This type of interaction is designed to increase student engagement and accelerate the learning process by promptly correcting misconceptions.

Quantitative Learning Outcomes

After explaining the system implementation context, the next analysis evaluated the impact of using web-based educational games on student learning outcomes and learning efficiency. This analysis was conducted by comparing data before and after the learning intervention using educational games. Based on the results of quantitative analysis and observational findings following the implementation of web-based educational games in fourth-grade elementary school mathematics, the research focused on two main indicators: learning efficiency and student interest in learning.

Analysis of learning outcomes showed a consistent increase after the implementation of web-based educational games. The average pretest score for students was 62.34, with a standard deviation of 8.12, indicating a relatively moderate level of initial concept mastery. After the learning intervention using educational games, the average posttest score increased to 78.91 with a standard deviation of 7.45. A paired-sample t-test confirmed that the difference was statistically significant ($t(31) = 9.27$; $p < 0.001$), with a large effect size (Cohen's $d = 1.64$). These results indicate that the use of web-based educational games improves students' understanding of mathematical concepts.

In addition to improving learning outcomes, learning efficiency has also improved significantly. The average time to complete learning tasks before using the educational game was 28.60 minutes. After the intervention, this time decreased to 21.40 minutes. Statistical tests showed that this decrease in task completion time was significant ($t(31) = 8.11$; $p < 0.001$), with a large effect size ($d = 1.43$). This finding indicates that students were able to complete learning activities more quickly without reducing the quality of learning outcomes. Table 1 presents descriptive statistics on learning outcomes and task completion time before and after the intervention.

Table 1. Descriptive Statistics of Learning Outcomes and Task Completion Time

Variables	N	Mean	Elementary School
Pretest of learning outcomes	32	62.34	8.12
Posttest of learning outcomes	32	78.91	7.45
Task time before (minutes)	32	28.60	4.80
Task time after (minutes)	32	21.40	4.10

Regarding learning interest, the questionnaire results showed an average score of 4.21 on a maximum of 5, indicating a high category. Enjoyment scored highest, followed by attention and continued willingness to participate in the learning process. These findings indicate that students responded positively to game-based learning and showed strong interest in the presented activities. Table 2 presents a summary of students' learning interest scores based on the indicators.

Table 2. Student Learning Interest Scores Based on Indicators

Indicator	Mean	Elementary School	Category
Attention	4.12	0.55	Tall
Pleasure	4.34	0.51	Very high
Sustainable will	4.17	0.58	Tall
Total average	4.21	0.46	Tall

Classroom observations corroborated the quantitative findings. During game-based learning, students demonstrated increased focus, active participation, and positive responses to system feedback. Student interaction with the learning material was more intense than in conventional learning, and engagement was relatively even across students.

Discussion

The results of this study provide empirical evidence that pedagogically designed web-based educational games can simultaneously improve elementary school students' learning efficiency and interest. The significant improvement in learning outcomes, accompanied by a reduction in task completion time, indicates that game-based learning media impacts not only cognitive achievement but also the quality of the learning process. From a cognitive perspective, the improvement in learning outcomes can be explained by the direct feedback mechanism and gradual challenges integrated into educational games. Immediate feedback allows students to quickly identify and correct errors, thereby reducing persistent misconceptions. The gradual challenges help students process material progressively based on their ability level, ultimately increasing information-processing efficiency. These findings align with the results of systematic reviews that emphasize the importance of quality instructional design in digital game-based learning, particularly in elementary education (Cai et al., 2022; Dan et al., 2024).

The reduction in task completion time without a decrease in the quality of learning outcomes indicates that educational games serve as a tool to optimize students' learning strategies. In this context, learning efficiency is understood not only as accelerating activities but also as an indicator that students are able to understand the material with a more manageable cognitive load. These results support the view that game-based learning can facilitate more effective learning when game elements are designed in alignment with instructional objectives (Pando Cerra et al., 2022). From an affective perspective, the high learning interest scores indicate that web-based educational games can activate students' intrinsic motivation. The fun and challenging elements in the games encourage students to stay engaged in learning without feeling stressed. This finding is consistent with meta-analyses of gamification, which report that game elements can increase student motivation and engagement, though the effects are highly context- and design-dependent (Li et al., 2023; Slamet & Meng, 2025).

However, the results of this study should be interpreted with caution. The observed increase in learning interest and efficiency could potentially be influenced by the novelty effect, given that using educational games is a new experience for students. Therefore, the long-term effectiveness of this medium needs to be tested through further research with a longitudinal design and a control group. Furthermore, this study remains limited to a single subject and a single school context, so the generalizability of the findings warrants further study. Overall, this discussion confirms that the success of educational games lies not solely in their entertainment value but rather in the alignment among game design, learning objectives, and outcome-based evaluation. With the right design approach and measurable evaluation, web-based educational games can be an effective and relevant learning strategy for elementary education.

Conclusions and Suggestions

Conclusions

This study shows that the development of a web-based educational game designed with a pedagogical approach can have a significant positive impact on the learning efficiency and interest of elementary school students. Improved learning outcomes, accompanied by a reduction in task completion time, indicate that game-based learning media not only contributes to cognitive achievement but also optimizes the learning process. In other words, learning becomes not only more engaging but also more effective in utilizing students' time and effort.

From a cognitive perspective, the significant increase in post-test scores indicates that in-game learning mechanisms such as immediate feedback and incremental challenges support a deeper understanding of mathematical concepts. These results reinforce the finding that quality instructional design is a key factor in the success of digital game-based learning in elementary education. Increased learning efficiency indicates that students are able to process information with a more manageable cognitive load, resulting in more focused and productive learning. From an affective perspective, the high learning interest score confirms that web-based educational games can activate students' intrinsic motivation. Learning that is perceived as enjoyable and challenging encourages active engagement and a positive attitude toward learning activities. These findings demonstrate that educational games function not only as entertainment but also as pedagogical tools that can strengthen student engagement in learning.

Methodologically, the application of a design and development research approach allows for a clear link between needs analysis, media design decisions, and measurable learning outcomes. This contributes to the study of learning media development by placing learning efficiency and learning interest as the primary evaluation indicators. Thus, this research provides an empirical basis for suggesting that web-based educational games can be used as supporting media for mathematics learning in elementary schools if systematically designed and evaluated.

Suggestions

Based on the findings and limitations of this study, several suggestions can be put forward for further development and research. First, further research is recommended involving a larger number of subjects and more diverse school contexts to increase the external validity and generalizability of the findings. The use of an experimental design with a control group can also strengthen causal conclusions regarding the effectiveness of web-based educational games. Second, further development of educational games can expand the scope of learning materials. Third, future research is recommended to examine the long-term impact of educational game use on knowledge retention, the development of learning strategies, and students' attitudes toward learning. Fourth, from a practical perspective, teachers and schools need support in integrating educational games into regular learning to ensure their use is not sporadic. Educational games should be positioned as part of a planned learning strategy, not simply as an additional activity. With this approach, web-based educational games have the potential to become a sustainable, innovative solution for improving the quality of learning in elementary schools.

Acknowledgments

The authors would like to thank the elementary school for granting permission and support during this research, as well as the teachers and students who actively participated in the data collection and implementation of the learning media. Appreciation is also extended to colleagues who provided constructive feedback during the design and evaluation stages of the web-based educational game. This research was made possible thanks to the cooperation and support of various parties who contributed to the smooth and quality implementation of the research.

References

Ahmad, N., Alias, F.A., Hamat, M., & Mohamed, S.A. (2024). Reliability analysis: application of Cronbach's alpha in research instruments. Pioneering the Future: Delving Into E-Learning's Landscape, 114–119.

Behnamnia, N., Kamsin, A., & Hayati, S. (2024). Impact of Digital Game-Based Learning on STEM education in Primary Schools: A meta-analysis of learning approaches. Innoeduca: International Journal of Technology and Educational Innovation, 10(2), 113–140. https://doi.org/10.24310/ijtei.102.2024.19694

Cai, Z., Mao, P., Wang, D., He, J., Chen, X., & Fan, X. (2022). Effects of scaffolding in digital game-based learning on student's achievement: A three-level meta-analysis. Educational Psychology Review, 34(2), 537–574. https://doi.org/10.1007/s10648-021-09655-0

Cheung, K.K.C., & Tai, K.W.H. (2023). The use of intercoder reliability in qualitative interview data analysis in science education. Research in Science & Technological Education, 41(3), 1155–1175. https://doi.org/10.1080/02635143.2021.1993179

Dan, NN, Nga, NT, Dung, TM, & others. (2024). Digital game-based learning in mathematics education at primary school level: A systematic literature review. Eurasian Journal of Mathematics, Science and Technology Education, 20(4), em2423. https://doi.org/10.29333/ejmste/14377

Izah, S.C., Sylva, L., & Hait, M. (2023). Cronbach's alpha: A cornerstone in ensuring reliability and validity in

environmental health assessment. ES Energy & Environment, 23, 1057. https://doi.org/10.30919/esee1057

Karakoç, B., Eryilmaz, K., Turan Özpolat, E., & Yildirim, .Ibrahim. (2022). The effect of game-based learning on student achievement: A meta-analysis study. Technology, Knowledge and Learning, 27(1), 207–222. https://doi.org/10.1007/s10758-020-09471-5

Li, M., Ma, S., & Shi, Y. (2023). Examining the effectiveness of gamification as a tool promoting teaching and learning in educational settings: a meta-analysis. Frontiers in Psychology, 14, 1253549. https://doi.org/10.3389/fpsyg.2023.1253549

McKenney, S., & Reeves, T. (2018). Conducting educational design research. Routledge. https://doi.org/10.4324/9781315105642

Pando Cerra, P., Fernández Álvarez, H., Busto Parra, B., & Iglesias Cordera, P. (2022). Effects of using game-based learning to improve the academic performance and motivation in engineering studies. Journal of Educational Computing Research, 60(7), 1663–1687. https://doi.org/10.1177/073563312210740

Richey, R. C., & Klein, J. D. (2014). Design and development research: Methods, strategies, and issues. Routledge. https://doi.org/10.4324/9780203826034

Sari, YI, & Usman, O. (2019). Effect of Learning Ability, Time Efficiency, Learning Motivation and Discipline of Students' Time on Interests of Use of E-Learning. Learning Motivation and Discipline of Students' Time on Interests of Use of E-Learning (December 31, 2019). https://doi.org/10.2139/ssrn.3512042

Slamet, TI, & Meng, C. (2025). Gamification in collaborative learning: Synthesizing evidence through meta-analysis. Journal of Computers in Education, 1–37. https://doi.org/10.1007/s40692-024-00349-4

Smarandache, IG, Maricutoiu, LP, Ilie, MD, Iancu, DE, & Mladenovici, V. (2022). Students' approach to learning: evidence regarding the importance of the interest-to-effort ratio. Higher Education Research & Development, 41(2), 546–561. https://doi.org/10.1080/07294360.2020.1865283

Wang, L.-H., Chen, B., Hwang, G.-J., Guan, J.-Q., & Wang, Y.-Q. (2022). Effects of digital game-based STEM education on students' learning achievement: A meta-analysis. International Journal of STEM Education, 9(1), 26. https://doi.org/10.1186/s40594-022-00344-0

Zhang, Q., & Yu, Z. (2022). Meta-Analysis on Investigating and Comparing the Effects on Learning Achievement and Motivation for Gamification and Game-Based Learning. Education Research International, 2022(1), 1519880. https://doi.org/10.1155/2022/1519880