

Virtual Mathematics Kits: Interactive Gamification for Numeracy Learning in Elementary Education

Suriyana¹, Yunika Afryaningsih¹, Aditya Pratama²

annasuriyana55@gmail.com, yunikaafryaningsih@unukalbar.ac.id, adityapratamabadra@unukalbar.ac.id

¹Faculty of Teacher Training and Education, Universitas Nahdlatul Ulama Kalimantan Barat, Pontianak, Indonesia

²Faculty of Engineering, Universitas Nahdlatul Ulama Kalimantan Barat, Pontianak, Indonesia

*Correspondence to: Suriyana

Universitas Nahdlatul Ulama Kalimantan Barat
email: annasuriyana55@gmail.com

Abstract: This study aimed to develop an interactive Virtual Mathematics Kit (VMK) integrated with a gamification approach and to examine its feasibility, practicality, and effectiveness in improving elementary school students' numeracy skills. The study was motivated by persistent low numeracy achievement and disparities in students' mathematical competencies, particularly in rural elementary schools. A Research and Development (R&D) approach was employed using the ADDIE model, comprising the Analysis, Design, Development, Implementation, and Evaluation stages. The participants were 26 fourth-grade elementary school students. The developed interactive VMK was validated by four expert validators in terms of content and media quality. Data were collected through observations, questionnaires, and pretest–posttest assessments and analyzed using descriptive statistics and normalized gain (N-gain) analysis. The validation results indicated that the VMK achieved a feasible category based on evaluations by both material and media experts. Practicality testing showed mean student response scores of 4.2 in individual trials and 3.6 in small-group trials, both categorized as practical. The effectiveness evaluation produced an average N-gain score of 0.58, indicating a moderate improvement in students' numeracy skills. These findings demonstrate that the gamification-integrated VMK is feasible, practical, and effective for supporting mathematics learning and reducing numeracy gaps among elementary school students. The study contributes to the development of technology-enhanced, gamified learning media to strengthen numeracy education, particularly in rural elementary school contexts.

Keywords: elementary education; gamification; interactive learning media; numeracy; vmk media

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Introduction

Technology-based interventions with gamification elements have been proven to improve students' learning outcomes, motivation, and engagement (Huang & Hew, 2021; Zainuddin et al., 2020). A recent meta-analysis reported that gamification has a significant positive effect on academic achievement, with the magnitude of the effect influenced by instructional design and learner characteristics (Li et al., 2023; Sailer & Homner, 2020). This finding suggests that gamified learning environments can provide meaningful support for mathematics learning, including the development of numeracy skills (Parra-González et al., 2021; Hamari et al., 2019; Dichev & Dicheva, 2017). The integration of gamification into mathematics instruction can therefore create more interactive learning experiences that encourage students to actively engage with mathematical concepts and persist in completing learning tasks. Moreover, when gamified elements are aligned with clear instructional objectives, they can function not merely as motivational features but also as pedagogical mechanisms that support meaningful learning and the development of students' numeracy competencies.

Several previous studies have investigated digital interventions to improve mathematical competencies (Bond et al., 2021; Prodromou & Lavicza, 2017). Pradana et al. (2020) found that Virtual Mathematics Kits (VMK) significantly enhanced elementary students' mathematical literacy through interactive visualization. Likewise, recent studies on adaptive digital learning environments indicate that personalized feedback and flexible learning pathways can improve students' engagement and conceptual understanding, especially for learners with different ability levels (Oumelaid et al., 2026; Li et al., 2023). However, most of these studies have focused

on mathematical literacy or general learning achievement rather than specifically addressing numeracy as a fundamental competency involving number sense, estimation, measurement, and quantitative reasoning (Goos et al., 2019; OECD, 2023). This gap indicates the need for digital learning interventions that explicitly target the multidimensional nature of numeracy rather than treating it solely as an extension of mathematical literacy. Furthermore, integrating interactive and adaptive digital features with numeracy-oriented tasks may provide a more targeted learning environment for developing students' ability to apply quantitative reasoning in diverse mathematical and real-world contexts.

In Indonesia, numeracy disparities remain a significant educational challenge, particularly in rural and underdeveloped regions such as West Kalimantan (OECD, 2023; Teresia, 2021). Limited infrastructure, insufficient access to interactive learning media, and variations in students' learning readiness reduce the effectiveness of numeracy learning programs (Suryani et al., 2022; Badan Kebijakan Pendidikan Dasar dan Menengah, 2024). Although digital learning media have been increasingly introduced, many existing applications emphasize content delivery without integrating adaptive gamification features that can adjust learning experiences according to students' initial abilities (Raj & Renumol, 2022). This condition highlights the need for learning solutions that are not only digitally accessible but also responsive to differences in students' numeracy competencies and learning needs. Furthermore, the integration of adaptive learning pathways and gamification could provide differentiated learning experiences that enable students to receive appropriate levels of challenge, feedback, and support according to their individual readiness.

A critical review of previous studies reveals that existing gamification-based mathematics media still have several limitations. First, many studies emphasize motivational aspects but provide limited evidence regarding their impact on improving numeracy skills. Second, adaptive features, such as scaffolding, differentiated levels of difficulty, and personalized feedback, are often absent, even though these components are important for accommodating students with diverse learning needs (Oumelaid et al., 2026; Vlachopoulos & Makri, 2024; Rivera Muñoz et al., 2022). Third, empirical studies conducted in elementary schools in rural Indonesia, particularly in West Kalimantan, remain limited, making it difficult to understand the practical implementation of adaptive digital learning media in authentic classroom settings (Lestari et al., 2026; Wijaya et al., 2018). These limitations highlight an urgent need for digital mathematics learning media that move beyond entertainment and general engagement toward targeted development of numeracy competencies through adaptive and pedagogically structured learning experiences. Addressing this gap is particularly important in rural educational contexts, where differences in learning readiness and limited access to interactive resources require more responsive and contextually appropriate instructional solutions.

Thus, this study addresses these limitations by developing and evaluating an interactive VMK integrated with a gamification approach designed to support elementary students' numeracy learning. The study not only examines the feasibility and practicality of the developed media but also evaluates its effectiveness in improving numeracy skills through a pretest-posttest design in the context of elementary education in West Kalimantan, thereby contributing to the growing literature on adaptive digital mathematics learning (Ilyas et al., 2026; Li et al., 2023; Prodromou & Lavicza, 2017). The novelty of this study lies in the integration of interactive VMK, gamification, and adaptive learning features within a numeracy-focused digital learning environment specifically designed for elementary students in a rural Indonesian context. By simultaneously examining product quality and learning effectiveness, this study provides empirical evidence on how adaptive gamified digital media can be used not only to increase students' engagement but also to strengthen their numeracy skills in an authentic classroom setting.

Methods

This study employed a Research and Development (R&D) approach (Creswell & Creswell, 2017) to develop an interactive Virtual Mathematics Kit (VMK) integrated with a gamification approach for elementary school numeracy learning. This approach aims to develop, validate, and evaluate educational products to ensure that they are feasible, practical, and effective for learning. The development process adopted the ADDIE instructional design model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. This study employed a Research and Development approach to develop an interactive VMK integrated with a gamification approach for elementary school numeracy learning. Research and Development is product development that goes through several processes of design, evaluation of product validity and production. Research and development function to validate existing products by testing the effectiveness or validation of products, in developing a product means updating or creating new existing products more effectively, practically and efficiently.

The development process adopted the ADDIE instructional design model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because it

provides a systematic and iterative framework for designing educational media. In addition, the model allows continuous revision through formative evaluation at each stage, ensuring that the developed product meets users' needs and educational objectives. This model is widely used in educational technology research because it facilitates the integration of learning theory, instructional design, and product validation. In this study, the ADDIE framework was specifically applied to guide the design and development of the interactive gamified VMK, ensuring that each stage was systematically connected to the identified numeracy learning needs. To design and develop the interactive gamified VMK, the ADDIE development procedure was used, involving five sequential and interconnected phases: Analysis, Design, Development, Implementation, and Evaluation.

The research process followed a systematic development procedure consisting of three main stages: Analysis, Design, and Development. In the Analysis stage, researchers identified learning problems, students' numeracy needs, curriculum requirements, and classroom conditions through observations and interviews with teachers, while also examining students' initial abilities and the limitations of existing learning media. The findings from this stage were used to formulate the development requirements for the Virtual Mathematics Kit (VMK), particularly in terms of content, learning activities, and technological features needed to support numeracy learning. In the Design stage, the researchers developed the structure and interface of the interactive VMK, formulated learning objectives, prepared learning materials, designed gamification elements including levels, points, badges, and challenges, and developed the assessment instruments. The resulting design served as the blueprint for transforming the identified learning needs into an interactive and gamified digital learning environment. In the Development stage, the VMK was developed using the GeoGebra application and integrated with the predetermined gamification features to support interactive mathematics learning. The developed product was subsequently evaluated through validation by media experts and subject matter experts, and revisions were conducted based on their suggestions to improve the quality, content accuracy, usability, and instructional appropriateness of the media. Consequently, these sequential stages produced a validated and revised interactive VMK that was considered ready for classroom implementation and subsequent evaluation of its practicality and effectiveness in supporting elementary students' numeracy learning.

This research was conducted at an elementary school in Kubu Raya Regency, West Kalimantan, involving 26 fourth-grade students as the research subjects. In addition, the product was validated by four experts consisting of two media experts and two subject matter experts. Data were collected using observation, questionnaires, and tests. Observations were conducted to obtain a direct description of the implementation process of the gamification-based Interactive VMK media and to identify students' responses and classroom interactions during learning activities. The questionnaire was used to evaluate the feasibility and practicality of the developed media. The validation questionnaire was administered to media experts and subject matter experts, while the practicality questionnaire was completed by students after using the media. The questionnaire employed a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The media validation instrument consisted of seven statements related to media design, usability, and gamification features, while the material validation instrument consisted of seven statements concerning content suitability, concept accuracy, and learning support. The student response questionnaire consisted of three statements evaluating ease of use, material understanding, and learning efficiency.

The test instrument was designed to measure the effectiveness of the interactive VMK in improving students' numeracy skills. A pretest and posttest design was employed using essay-based questions that focused on geometry and angle measurement concepts. The test consisted of five numeracy questions covering several indicators, namely: (1) identifying and classifying angles, (2) measuring angles correctly, (3) solving contextual problems involving angles, (4) applying mathematical reasoning to everyday situations, and (5) interpreting quantitative information related to geometric concepts. The data were analyzed using descriptive qualitative and descriptive quantitative techniques. The feasibility and practicality of the media were analyzed using the average scores obtained from expert validation and student response questionnaires. The effectiveness of the developed media was analyzed using the normalized gain (N-Gain) test by comparing students' pretest and posttest scores. The N-Gain analysis was used to determine the level of improvement in students' numeracy skills after using the interactive VMK, as well as to evaluate the effectiveness of the developed learning media.

Result and Discussion

The results in this study, the researcher conveyed the results in accordance with the development research method used in this study is the ADDIE model. The ADDIE model is the development of a product with a model that is simple in a systematic manner, but does not reduce an outcome. The ADDIE model is simple in its procedure, but the implementation remains systematic. In the analysis stage, classroom observations and interviews with teachers were carried out to identify the initial conditions of mathematics learning and the need

for the development of digital learning media. The results of the analysis show that mathematics learning at one of rural state elementary school is still dominated by conventional methods of limited media use. Teachers generally use textbooks and verbal explanations, so students have difficulty understanding abstract mathematical concepts, especially angular and geometric measurement materials. In addition, it was found that there was a gap in numeracy skills between students. Based on the results of observations, most students were able to solve routine problems, but still experienced difficulties when faced with contextual problems that required quantitative reasoning. The results of interviews with teachers also show that students often make mistakes in identifying the type of angle, determining large angles, and connecting mathematical concepts to everyday life situations.

Other findings show that the available learning media does not provide interactive features or feedback that can adapt to students' initial abilities. This condition causes students with low abilities to require more intensive assistance, while students with high abilities do not receive adequate learning challenges. Based on the results of the analysis, a GeoGebra-based Interactive VMK was developed with a gamification approach that integrates interactive visualization, learning challenges, point systems, levels, and badges as an effort to increase learning motivation and improve students' numeracy skills. The integration of these features was intended to provide a more responsive learning environment in which students could engage with mathematical concepts through different levels of challenge according to their learning readiness (Li et al., 2026; Yabashiru et al., 2025). Furthermore, the combination of interactive visualization and gamification was designed to encourage active participation while providing structured opportunities for students to practice and strengthen their numeracy competencies.

In the design stage, based on the results of the needs analysis, an Interactive VMK was designed that integrates the concept of numeracy with a gamification approach. The product is designed to be able to facilitate the exploration of angular concepts independently through the GeoGebra application. Based on the results of needs analysis, an Interactive VMK was designed that integrates the concept of numeracy with a gamification approach. The product is designed to be able to facilitate the exploration of angular concepts independently through the GeoGebra application to produce prototype media consisting of several main components, namely: (1) main page (main menu), (2) instructions for use, (3) interactive learning materials, (4) exploration activities using GeoGebra, (5) challenges, (4) points and badge systems, (7) evaluating learning. Media design also considers the characteristics of elementary school students with the use of simple visual displays, eye-catching colors, and easy-to-use navigation. The integration interactive media would support mathematical learning for students difficulties (Fauzan, 2025; Bang, et al., 2023)

The development stage produced an Interactive VMK integrated with GeoGebra and a gamification approach for fourth-grade elementary school students. The product was designed to improve students' numeracy skills, particularly in learning angle measurement and basic geometry concepts. The developed VMK consists of several interconnected features that support interactive and adaptive learning. Based on these findings, an interactive VMK was designed by integrating gamification elements, including points, badges, levels, and learning challenges. The media also incorporated adaptive features through graduated learning tasks, scaffolding, and immediate feedback. These features were intended to provide additional guidance for students with lower initial abilities while offering more challenging activities for students with higher abilities. The development of the media was guided by Constructivist Theory, which emphasizes active knowledge construction through meaningful learning experiences, and Multimedia Learning Theory, which explains that the integration of visual and verbal information can facilitate students' cognitive processing (Mayer, 2020). Furthermore, Self-Determination Theory supports the use of gamification elements to increase students' motivation and engagement by promoting autonomy and competence (Muchuweni & Jojo, 2026; Nurmaltiefa et al., 2026).

Produced VMK Interactive products which were then validated by two media experts and two material experts. The results of the validation of media experts showed (**Table 1**) that VMK Interactive obtained an average score of 3.4 with the decent category. The validators assessed that the display media, mathematical visualization, and integration of GeoGebra features were suitable for use in mathematics learning. Meanwhile, the results of the validation of the subject matter experts obtained an average score of 4.1 with the feasible category. The validator stated that the material presented was in accordance with basic competencies, learning indicators, and was able to support the strengthening of students' numeracy. These findings show that the developed media has met the feasibility aspects both in terms of design and material content so that it is feasible to be implemented in learning.

Table 1. Media and Subject Matter Expert Validation Results

No	Statement	Average Score
Media Expert Validation Results		
1	Media layouts (menus, buttons, work areas) are clear and proportional.	4
2	Mathematical visualizations (graphs, objects, animations) are clear and easy to understand	3
3	Media is easy to run through the GeoGebra application (offline/online).	3
4	GeoGebra features are optimally utilized (geometry tools, graphs, sliders).	4
5	There are gamification elements (levels, points, badges, scores, challenges).	
6	The media is easy to use by teachers and elementary school students.	3
7	Instructions for using the app (how to open, run, repeat) are available.	4
	Average Score	3.4
Material Expert Validation Results		
1	Suitability of the material with Basic Competencies	4.5
2	Compatibility of the indicator with KD	4
3	The truth of the concept of material is in accordance with its scientific point of view	4
4	Availability of question discussion exercise	4.5
5	Explanation of the material in the media is appropriate and clear	4
6	Learning media using geogebra applications can support the learning process	4
7	students to Self-study in determining angles	4
	Average Score	4.1

The results of the design were validated by media experts and material experts. The assessment of media experts gave a score of 3.4 with a decent category, while material experts gave a score of 4.1 with a decent category. This shows that the design of interactive VMK media is in accordance with the principles of mathematics learning and the needs of students. The feasibility evaluation was conducted by four expert validators consisting of mathematics education experts, educational technology experts, and a language expert. The validation process assessed content quality, instructional design, language, visual appearance, and usability. The validation results indicated that the developed VMK met the feasibility criteria and was appropriate for classroom implementation. The experts suggested several revisions related to interface design and instructional clarity, which were incorporated before the implementation stage. These findings indicate that the integration of interactive visualization and gamification produced a learning medium that is pedagogically and technically appropriate. Similar findings were reported that interactive VMK supports students' understanding of mathematical concepts through visual exploration (Ni et al., 2026; Pradana et al., 2020). Likewise, Prodromou & Lavicza (2017) emphasized that technology-enhanced mathematics learning environments improve instructional quality and students' learning experiences.

Researchers conducted individual trials and small group trials to identify the effectiveness and practicality of the developed learning media. The individual trial was carried out to four grader of rural state elementary school. Individual trials were carried out on 3 students, trials were carried out to find out practicality through questionnaires. After the interactive VMK media through the geogebra application with a gamification approach to the geothermal material, the section measures the angle. In the use of the geogebra application, students are asked to do an adventure in completing the game. The practical trial is the implementation of interactive VMK media through the geogebra application with a gamification approach that is revised by media experts and material experts at the development stage. A practicality trial was carried out to determine the practicality of using learning media by involving individual and small group trials.

Table 2. Results of Individual Trials

No	Indicator	Responden			Average
		1	2	3	
1	Interactive VMK media through geogebra applications with an easy-to-use gamification approach	4	4	5	4.3
2	The material presented in Interactive VMK media through the geogebra application with a gamification approach is easy for you to understand	4	4	4	4
3	By using Interactive VMK media through the geogebra application with a gamification approach, learning time is more efficient	5	5	4	4,3
		Average			4.2

The small group trial was carried out on 13 students in for grader of rural elementary school in West Kalimantan with the aim of finding out the level of practicality in the use of interactive VMK media through the geogebra application with a gamification approach and the results in the table.

Table 3. Results of Small Group Trials

No	Indicator	Average
1	Interactive VMK media through geogebra applications with an easy-to-use gamification approach	4.1
2	The material presented in Interactive VMK media through the geogebra application with a gamification approach is easy for you to understand	3.8
3	By using Interactive VMK media through the geogebra application with a gamification approach, learning time is more efficient	3.9
Average		3.6

Based on these calculations (**Table 2**), the average product validation of the practicality aspect in the individual trial was 4.2 with the partial category. While based on this calculation (**Table 3**), the average product validation of the practicality aspect in the small group trial was obtained, namely 3.6 the practicality of interactive VMK media through the geogebra application with a gamification approach is in the range of $3.4 < M \leq 4.2$ with "practical" criteria. Based on the results of the calculation, the media developed is categorized as "practical". The practicality of the developed media was evaluated through student response questionnaires during the implementation stage. The results showed that students perceived the interactive VMK as easy to use, attractive, and helpful for learning mathematics. The positive responses suggest that the gamification features successfully increased students' participation and learning engagement. The use of points, levels, and badges encouraged students to complete learning activities and provided immediate reinforcement for their achievements. According to Self-Determination Theory, these elements may strengthen students' sense of competence and intrinsic motivation (Muchuwani & Jojo, 2026). This finding is also supported by Hamari et al. (2019), Dichev and Dicheva (2022), and Zainuddin et al. (2020), who concluded that gamification can improve engagement and active participation in learning environments.

The implementation stage involved applying the interactive VMK media with a gamification approach to support students' numeracy learning. Before the intervention, students completed a pretest to measure their initial numeracy abilities and understanding of the learning materials. The interactive VMK media was then implemented through the GeoGebra application, with gamification elements integrated into the learning activities to facilitate students' engagement and participation. After completing the learning activities, students were administered a posttest to measure changes in their numeracy performance following the intervention. The effectiveness of the interactive VMK was assessed by comparing students' pretest and posttest scores using the N-gain analysis. The N-gain score was used to determine the magnitude of improvement in students' learning outcomes following the implementation of the interactive VMK with the gamification approach. Thus, the comparison between pretest and posttest results provided an indication of the extent to which the developed media supported students' numeracy understanding and mastery of the learning material.

The average pretest score of the students before using the Interactive VMK media was 39, with the lowest score of 10 and the highest score of 65. After the implementation of the media, the average posttest score increased to 73.87, with the lowest score of 40 and the highest score of 100. The N-gain analysis yielded an average score of 0.58. According to the N-gain classification, this value falls within the interval of $0.3 \leq g < 0.7$, which is categorized as moderate. This finding indicates that the Interactive VMK media based on GeoGebra contributed to a moderate improvement in students' numeracy skills. Although the effectiveness did not reach the high category, the results demonstrate that the integration of interactive visualization and gamification elements can support students in understanding mathematical concepts and improving their learning outcomes. Therefore, it can be elaborate that the Interactive VMK media based on GeoGebra are effective in improving students' numeracy skills with a moderate level of effectiveness.

The results of this study indicate that the implementation of the Interactive VMK with a gamification approach helps students understand the concept of angles in a more engaging, interactive, and adaptive way. This finding is consistent with constructivist learning theory, which emphasizes that hands-on learning experiences and interactive visualization can strengthen students' understanding of abstract mathematical concepts (Aldi et al., 2025; Romdhon et al., 2024). The effectiveness of the developed media was examined using a one-group pretest-posttest design. The N-Gain analysis indicated that students experienced a moderate improvement in numeracy skills after participating in learning activities using the interactive VMK. Although this study did not employ a comparison group, the observed improvement suggests that the interactive VMK can support elementary students' numeracy learning. The adaptive features integrated into the media, including

scaffolding, graduated tasks, and immediate feedback, enabled students with different initial ability levels to learn according to their individual progress. Lower-achieving students received additional learning support, while higher-achieving students were encouraged to solve more challenging problems.

These findings are consistent with studies by Li et al. (2023) and Oumelaid et al. (2026), which reported that adaptive digital learning environments improve conceptual understanding and student engagement. In addition, Multimedia Learning Theory suggests that interactive visual representations facilitate cognitive processing and strengthen mathematical understanding (Mayer, 2020). The findings also support the results of Sailer and Homner (2020), who found that gamification contributes positively to students' learning performance and motivation. The present study extends previous VMK research by integrating interactive media, gamification strategies, and adaptive learning support within a single digital learning environment. Unlike previous studies that mainly focused on media validity or students' motivation, this study also provides empirical evidence regarding the practicality and effectiveness of adaptive VMK for supporting elementary school students' numeracy development.

In the evaluation stage, analysis and improvement of interactive VMK media were carried out based on the input received. The data analysis in this study is based on the discussion, namely the results of media expert media validation, material expert media validation, individual trials (pretest-posttest and practicality questionnaire), small group trials (pretest-posttest and practicality questionnaire).

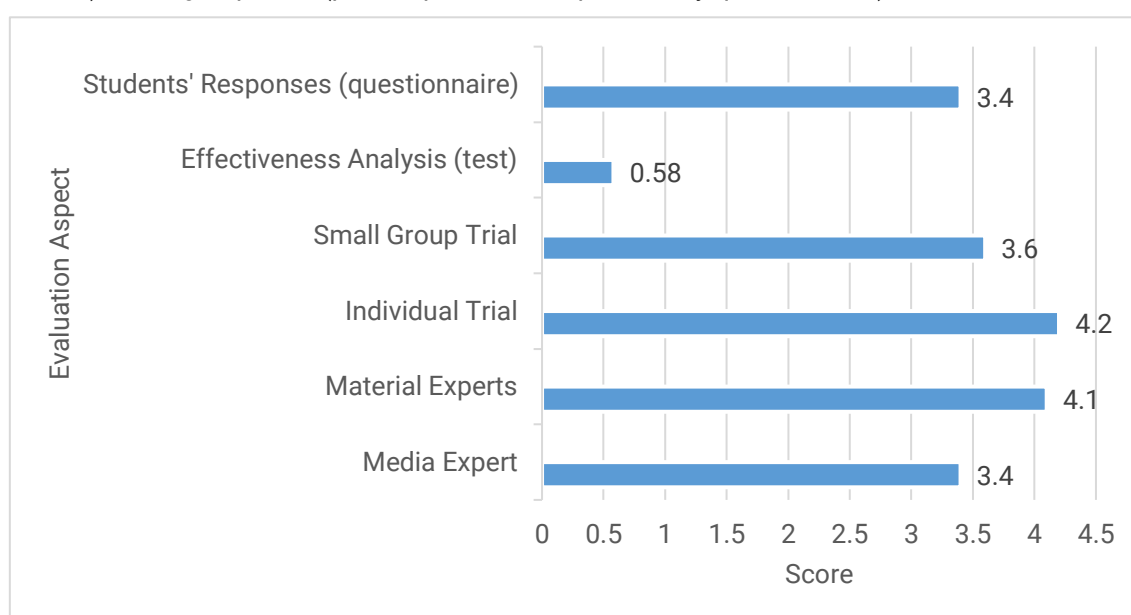


Figure 1. Recapitulation of Evaluation Results

Based on the data analysis presented in the table, the developed interactive VMK met the established feasibility criteria based on expert validation. The media expert validation resulted in an average score of 3.4, indicating that the media was categorized as feasible, while the subject matter expert validation obtained an average score of 4.1, also indicating a feasible category. At the individual trial stage, the practicality assessment produced an average score of 4.2, which was categorized as practical, while the small-group trial obtained an average score of 3.6, also within the practical category. During the implementation stage, the interactive VMK was tested with four grade stuents of rural area of elementary school in West Kalimantan, and its effectiveness was examined by comparing students' pretest and posttest scores. The analysis resulted in an average N-gain score of 0.58, which falls to categorized as moderate. The students' response questionnaire also produced an average score of 3.4, indicating that the interactive VMK was categorized as practica from the students' perspective. Evaluation was conducted through both formative and summative processes, in which formative evaluation involved expert feedback and trial results to refine the media, whereas summative evaluation assessed the overall quality and effectiveness of the final product. Overall, the findings demonstrate that the gamification-based interactive VMK is feasible as a learning medium based on expert validation, practical based on student responses, and effective in improving students' numeracy skills, as indicated by the moderate average N-gain score. Gamification could improved students' numeracy skills (Fatmawati & Hasim, 2026; Duraiswamy & Mohammed, 2024).

Nevertheless, several limitations should be acknowledged. The use of a one-group pretest-posttest design without a control group limits the ability to establish causal relationships. In addition, the relatively small sample size and implementation in a single school may reduce the generalizability of the findings. Future

studies are recommended to involve larger samples, comparison groups, and more comprehensive statistical analyses to strengthen the evidence regarding the effectiveness of adaptive gamification-based mathematics learning media. Despite these limitations, the study provides an important contribution to elementary education by demonstrating the potential of interactive and gamified digital media to support numeracy learning. The integration of interactive visualization, gamification, and adaptive learning features offers an alternative approach for creating more engaging and responsive mathematics learning experiences for elementary school students. From a pedagogical perspective, the developed VMK can support teachers in providing varied learning challenges and opportunities for students to actively practice numeracy skills according to their learning needs. Therefore, this study provides a foundation for further development of technology-enhanced mathematics instruction that is more adaptive, student-centered, and relevant to the demands of contemporary elementary education.

Conclusion

The findings indicate that the developed interactive VMK media is fulfilled the feasibility criteria based on expert evaluations and was considered practical according to students' responses during classroom implementation. Furthermore, the effectiveness analysis showed a moderate improvement in students' numeracy skills after using the interactive VMK. The integration of interactive visualization, gamification elements, and adaptive learning support provides an alternative approach for enhancing students' engagement and facilitating mathematics learning. The developed media may assist teachers in creating more interactive and student-centered learning environments, particularly for elementary mathematics instruction. However, several limitations should be acknowledged. This study employed a one-group pretest-posttest design without a control group, which limits the ability to establish causal relationships regarding the effectiveness of the intervention. In addition, the relatively small sample size and the implementation in a single school may restrict the generalizability of the findings to broader educational contexts. Future studies are recommended to involve larger samples, include comparison or control groups, and employ more comprehensive statistical analyses to provide stronger empirical evidence regarding the effectiveness of adaptive gamification-based learning media. Further research may also explore the implementation of interactive VMK in different mathematics topics and educational settings to better understand its potential contribution to elementary mathematics learning.

Author Contributions

S and YA contributed to the conceptualization and methodology of the study. S, YA, and AP carried out the formal analysis and investigation. S prepared the original draft, while YA and AP contributed to writing, reviewing, and editing the manuscript.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Use of Artificial Intelligence

Generative AI was used (Claude) to assist in drafting portions of the manuscript. All AI-generated text was critically reviewed, revised, and verified by the authors. The authors assume full responsibility for the accuracy and integrity of the final manuscript.

References

- Aldi, M., Azzahra, F., Aminullah, M., & Susilawati, S. (2025). Optimizing the learning process through theory-based media selection: Constructivist, cognitive, collaborative, and motivational perspectives. *Electronic Journal of Education, Social Economics and Technology*, 6(1), 423-430. <https://doi.org/10.33122/ejeset.v6i1.209>
- Badan Kebijakan Pendidikan Dasar dan Menengah. (2024). *Rapor Pendidikan Indonesia 2023*.

Kementerian Pendidikan Dasar dan Menengah.
<https://data.kemendikdasmen.go.id/publikasi/p/rapor-pendidikan-indonesia/rapor-pendidikan-indonesia-2024>

- Bang, H. J., Li, L., & Flynn, K. (2023). Efficacy of an adaptive game-based math learning app to support personalized learning and improve early elementary school students' learning. *Early Childhood Education Journal*, 51(4), 717-732. <https://doi.org/10.1007/s10643-022-01332-3>
- Bond, M., Bedenlier, S., Marín, V. I., & Händel, M. (2021). Emergency remote teaching in higher education: Mapping the first global online semester. *International Journal of Educational Technology in Higher Education*, 18(1), 50. <https://doi.org/10.1186/s41239-021-00282-x>
- Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
- Dichev, C., & Dicheva, D. (2017). Gamifying education: What is known, what is believed and what remains uncertain: A critical review. *International Journal of Educational Technology in Higher Education*, 14(1), 9. <https://doi.org/10.1186/s41239-017-0042-5>
- Duraiswamy, M., & Mohammed, L. A. (2024). The effects of gamification teaching method in enhancing numeracy learning among primary school students in Tamil Nadu. *International Journal of Emerging Issues in Social Science, Arts and Humanities (IJEISSAH)*, 2(2), 22-34. <https://doi.org/10.60072/ijeissah.2024.v2i02.003>
- Fatmawati, F., & Hasim, W. (2026). The Effect of Interactive Wordwall Media on Improving Elementary School Students' Mathematical Numeracy Skills. *JTMT: Journal Tadris Matematika*, 7(1), 51-59. <https://doi.org/10.47435/jtmt.v7i1.4490>
- Fauzan, F. (2025). Development of a diagnostic test for mathematics learning difficulties in elementary school. *The Journal of Academic Science*, 2(6), 1628-1638. <https://doi.org/10.59613/e30nrs70>
- Goos, M., Geiger, V., Dole, S., Forgasz, H., & Bennison, A. (2019). *Numeracy across the curriculum: Research-based strategies for enhancing teaching and learning* (1st ed.). Allen & Unwin.
- Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior*, 54, 170-179. <https://doi.org/10.1016/j.chb.2015.07.045>
- Huang, B., & Hew, K. F. (2018). Implementing a theory-driven gamification model in higher education flipped courses: Effects on out-of-class activity completion and quality of artifacts. *Computers & Education*, 125, 254-272. <https://doi.org/10.1016/j.compedu.2018.06.018>
- Ilyas, M. M., Akib, I., & Muzaini, M. (2026). GeoGebra-assisted instructional strategies for developing the students' mathematical communication skills: A systematic review in Indonesian high schools. *International Journal on Education Insight*, 7(1), 77-98. <https://doi.org/10.12928/ijeiv.v7i1.14955>
- Lestari, P., Andarani, E. T., Subali, B., & Widiyatmoko, A. (2026). Literature Review (2020-2025): Numeracy development and mathematics learning models in elementary schools. *Journal of Educational Sciences*, 10(3), 392-403. <https://doi.org/10.31258/jes.10.3.p.392-403>
- 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>
- Li, M., Vale, C., Tan, H., & Blannin, J. (2026). Technological pedagogical readiness: Examining TPACK, educational ecosystem, and teacher attitudes in Chinese primary mathematics education. *International Electronic Journal of Mathematics Education*, 21(2), em0880. <https://doi.org/10.29333/iejme/18282>
- Mayer, R. E. (2020). *Multimedia learning* (3rd ed.). Cambridge University Press. <https://doi.org/10.1017/9781316941355>
- Muchuwani, T., & Jojo, Z. (2026). Gamification in the US mathematics classroom: International

- teachers' perceived impact on student engagement and motivation. *International Journal of Learning, Teaching and Educational Research*, 25(3), 1033-1050. <https://doi.org/10.26803/ijlter.25.3.46>
- Ni, X., Nuryana, Z., Lu, S., & Xu, W. (2026). A systematic literature review of mathematics interactive games in elementary education. *Interactive Learning Environments*, 34(4), 1992-2019. <https://doi.org/10.1080/10494820.2025.2538745>
- Nurmultiefa, B., Monika, D., Rahmawati, D. D., & Ariswati, E. (2026). The application of a gamification approach to enhance motivation in learning mathematics among fourth-grade elementary school students. *Journal of Asian Primary Education (JoAPE)*, 3(1), 27-33. <https://doi.org/10.59966/joape.v3i1.2714>
- OECD. (2023). *PISA 2022 results (Volume II): Learning during – and from – disruption*. OECD Publishing. <https://doi.org/10.1787/a97db61c-en>
- Oumelaid, N., Talibi, I., El Boukari, B., & El Ghordaf, J. (2026). Digital learning environments and mathematical achievement: An empirical investigation of motivation-performance dynamics through self-determination theory. *Learning and Motivation*, 95, 102311. <https://doi.org/10.1016/j.lmot.2026.102311>
- Parra-González, M. E., López-Belmonte, J., Segura-Robles, A., & Moreno-Guerrero, A. J. (2021). Gamification and flipped learning and their influence on aspects related to the teaching-learning process. *Heliyon*, 7(2), Article e06254. <https://doi.org/10.1016/j.heliyon.2021.e06254>
- Pradana, L. N., Sholikhah, O. H., Maharani, S., & Kholid, M. N. (2020). Virtual mathematics kits (VMK): Connecting digital media to mathematical literacy. *International Journal of Emerging Technologies in Learning (iJET)*, 15(03), 234–241. <https://doi.org/10.3991/ijet.v15i03.11674>
- Prodromou, T., & Lavicza, Z. (2017). Integrating technology into mathematics education in an entire educational system—reaching a critical mass of teachers and schools. *International Journal for Technology in Mathematics Education*, 24(3), 129-135. https://doi.org/10.1564/tme_v24.3.04
- Raj, N. S., & Renumol, V. G. (2022). A systematic literature review on adaptive content recommenders in personalized learning environments from 2015 to 2020. *Journal of Computers in Education*, 9(1), 113-148. <https://doi.org/10.1007/s40692-021-00199-4>
- Rivera Muñoz, J. L., Moscoso Ojeda, F., Aparicio Jurado, D. L., & Puga Peña, P. F. (2022). Systematic review of adaptive learning technology for learning in higher education. *Eurasian Journal of Educational Research*, 98, 221–233. <https://doi.org/10.14689/ejer.2022.98.014>
- Romdhon, J., Masrifah, M., Shiyama, N. M., & Suharyati, H. (2024). Applying constructivist learning theory to enhance student learning outcomes in elementary schools. *International Journal of Sustainable Development & Future Society*, 2(2), 62-69.. <https://doi.org/10.62157/ijdsdfs.v2i2.73>
- Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. *Educational Psychology Review*, 32(1), 77–112. <https://doi.org/10.1007/s10648-019-09498-w>
- Teresia, W. (2021). *Asesmen Nasional 2021*. Guepedia.
- Vlachopoulos, D., & Makri, A. (2024). A systematic literature review on authentic assessment in higher education: Best practices for the development of 21st century skills, and policy considerations. *Studies in Educational Evaluation*, 83, 101425. <https://doi.org/10.1016/j.stueduc.2024.101425>
- Wijaya, A., Van den Heuvel-Panhuizen, M., Doorman, M., & Veldhuis, M. (2018). Opportunity-to-learn to solve context-based mathematics tasks and students' performance in solving these tasks – Lessons from Indonesia. *Eurasia Journal of Mathematics, Science and Technology Education*, 14(10), em1598. <https://doi.org/10.29333/ejmste/93420>
- Yabashiru, F., Apriza, B., & Dinata, K. B. (2025). Mathematics learning difficulties among elementary school students. *Journal for Lesson and Learning Studies*, 8(2), 304-315. <https://doi.org/10.23887/jlls.v8i2.94756>
- Zainuddin, Z., Chu, S. K. W., Shujahat, M., & Perera, C. J. (2020). The impact of gamification on learning and instruction: A systematic review of empirical evidence. *Educational Research Review*, 30, 100326. <https://doi.org/10.1016/j.edurev.2020.100326>