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Development of Website-Based Gamification Media for Improving Fourth-Grade Students' Mathematical Conceptual Understanding of Spatial Geometry

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ABSTRACT

Elementary school students often experience difficulties in understanding mathematical concepts in spatial geometry because the material is abstract and learning activities are not always supported by interactive media. This study aimed to develop website-based gamification media designed to support fourth-grade students' mathematical conceptual understanding of spatial geometry. The study employed a Research and Development (R&D) approach using the 4D development model consisting of Define, Design, Develop, and Disseminate stages. The research was conducted at SD Negeri Kuin Utara 4 Banjarmasin and involved 26 fourth-grade students as trial participants. Data were collected through expert validation sheets, teacher and student response questionnaires, and pretest and posttest instruments. The data were analyzed using percentage analysis, descriptive statistics, a Shapiro–Wilk normality test, a Paired Sample t-test, and Normalized Gain (N-Gain). The validation results showed that the media expert assessment reached 72%, while the material expert assessment reached 71.6%, both categorized as good. The N-Gain score was 0.6208, indicating a moderate level of improvement in students' mathematical conceptual understanding. The Paired Sample t-test also showed a significant difference between students' pretest and posttest scores ($p < 0.05$)

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1. INTRODUCTION

The development of digital technology has brought significant changes to education. Technology is no longer used merely as a tool for delivering information but has increasingly become part of learning environments that promote interaction, flexibility, and student-centered learning. In the context of 21st-century education, the integration of technology is expected to support critical thinking, creativity, communication,

collaboration, and digital literacy (Zuhri et al., 2024). This direction is also consistent with the implementation of the Independent Curriculum, which emphasizes active, contextual, and meaningful learning experiences.

Mathematics learning in elementary schools requires students not only to memorize formulas and procedures but also to develop a meaningful understanding of mathematical concepts. Mathematical conceptual understanding involves the ability to explain concepts, recognize relationships among concepts, represent concepts in different forms, and apply concepts to mathematical and everyday situations. Previous research has shown that students' understanding of mathematical concepts is an important foundation for solving mathematical problems and developing further mathematical knowledge (Pratama et al., 2022; Wahyuni & Prihatiningtyas, 2020).

Spatial geometry is one of the mathematics topics that may present difficulties for elementary school students because many of its objects and properties are abstract. Students need to understand characteristics, relationships, and representations of three-dimensional objects rather than merely memorize their names. Therefore, learning activities that provide visual representations, illustrations, videos, and opportunities for interaction may help students connect abstract mathematical ideas with more concrete representations. The use of multimedia is relevant to Mayer's Multimedia Learning theory, which explains that learning can be supported when verbal and visual information are presented through appropriately designed multimedia. Effective multimedia design should help learners select, organize, and integrate relevant information rather than simply increase the amount of information presented (Mayer, 2020).

Website-based learning media provides an opportunity to integrate different forms of instructional content within a single learning environment. Learning materials, illustrations, instructional videos, interactive quizzes, and feedback can be presented through a website that students can access during learning activities. Previous research has reported that website-based media can support mathematics learning and increase students' engagement (Suryandaru & Setyaningtyas, 2021), while digital and interactive media have also been reported to provide more engaging learning experiences for elementary students.

In addition to multimedia, gamification can be incorporated into digital learning environments to encourage students' active participation. Gamification refers to the integration of game-related elements into non-game contexts. In learning, elements such as points, levels, badges, rewards, challenges, timers, and immediate feedback can provide students with clear goals and feedback during learning activities. Previous studies have reported positive relationships between gamification and students' motivation, participation, and engagement in learning mathematics (Irnawati et al., 2024; Jutin & Maat, 2024; Valentinna et al., 2024). However, increased engagement should not be assumed to directly produce conceptual understanding. A more plausible learning mechanism is that gamification encourages students to participate and interact with learning activities for longer periods, while multimedia representations and feedback provide opportunities to process and correct their understanding.

Based on this perspective, the integration of multimedia and gamification may provide a learning environment in which students are encouraged to engage with mathematical representations, complete learning challenges, receive immediate feedback, and repeatedly practice applying concepts. In spatial geometry, interactive visualizations can help students observe properties of geometric objects, while quizzes and feedback can provide opportunities to test and revise their understanding. Thus, the

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potential contribution of website-based gamification lies not only in making learning more enjoyable but also in creating more opportunities for active conceptual processing.

Previous studies have demonstrated the potential of gamification and website-based media in mathematics education. Khauli, Nasution, and Karimah (2022), for example, reported that gamification-based learning media for spatial geometry was valid and suitable for learning. Novitasari et al. (2023) found that website-based learning media could increase student engagement in mathematics learning. Other studies have primarily examined outcomes such as motivation, interest, participation, or general learning achievement.

The preliminary study conducted at SD Negeri Kuin Utara 4 Banjarmasin through observations and interviews with fourth-grade teachers indicated that mathematics learning on spatial geometry was still dominated by textbooks, whiteboards, and simple presentation media. Teachers reported that students experienced difficulties in understanding spatial geometry because of the abstract nature of the material and the limited availability of interactive learning media. Students were also observed to be less active and easily bored during learning activities. Furthermore, website-based gamification had not previously been implemented in mathematics learning at the school.

These findings indicate a need for learning media that combines mathematical content, multimedia representations, interactive activities, and gamification within an accessible digital environment. Although previous research has demonstrated the potential of gamification and website-based learning media, the present study focuses specifically on the development of website-based gamification media for supporting fourth-grade students' mathematical conceptual understanding of spatial geometry. The novelty of this research therefore lies in integrating multiple gamification elements—points, badges, levels, rewards, timers, lives, and automatic feedback—with multimedia learning activities in a website-based mathematics learning environment.

Accordingly, this study aimed to develop website-based gamification media for fourth-grade students' mathematical conceptual understanding of spatial geometry and to examine its validity and preliminary effectiveness based on expert validation and changes in students' pretest and posttest performance.

2. METHODS

This study employed a Research and Development (R&D) approach using the Four-D (4D) development model proposed by Thiagarajan, Semmel, and Semmel (1974). The model consists of four stages: Define, Design, Develop, and Disseminate. The model was selected because it provides a systematic procedure for identifying learning needs, designing instructional products, developing and validating the product, and conducting limited dissemination.

In this study, the Disseminate stage was conducted on a limited basis at SD Negeri Kuin Utara 4 Banjarmasin. The limited dissemination was intended to obtain initial user responses and examine the use of the developed media in an authentic elementary mathematics learning context

The study was conducted at SD Negeri Kuin Utara 4 Banjarmasin during the even semester of the 2025/2026 academic year. The trial participants consisted of 26 fourth-grade students and one fourth-grade teacher. Participants were selected purposively based on the results of preliminary observations and interviews indicating difficulties in students' understanding of spatial geometry and limited use of interactive technology-based learning media.

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The Define stage involved identifying the learning problems, analyzing students' characteristics, analyzing the spatial geometry content, and formulating learning objectives. The analysis indicated a need for interactive learning media that could present abstract spatial geometry concepts through visual and interactive representations.

The Design stage involved preparing the learning structure and prototype of the website-based gamification media. The researchers developed the flowchart, storyboard, interface design, learning materials, interactive quizzes, and gamification features. The gamification elements included points, badges, levels, rewards, timers, lives, and automatic feedback. Learning activities were designed to encourage students to interact with mathematical representations, complete challenges, and receive feedback on their responses.

The Develop stage involved realizing the initial design into a functional website-based learning medium. The product was then evaluated by media and material experts. Revisions were made based on the experts' comments and suggestions before the product was implemented with students.

The Disseminate stage was conducted through limited implementation with the fourth-grade teacher and students at the research school. Teacher and student responses were collected to obtain initial information about the usability and attractiveness of the developed media

The research instruments consisted of expert validation sheets, teacher and student response questionnaires, and mathematical conceptual understanding tests in the form of pretest and posttest.

The media validation instrument assessed aspects related to visual appearance, interface design, navigation, interactivity, technical functionality, and suitability of the media for learning. The material validation instrument assessed the suitability and accuracy of the mathematics content, clarity of presentation, alignment with learning objectives, and appropriateness of the material for fourth-grade students. The teacher and student response questionnaires were used to obtain information about the practicality, attractiveness, ease of use, and perceived usefulness of the media.

The pretest and posttest were designed to measure students' mathematical conceptual understanding of spatial geometry. The conceptual understanding indicators included: (1) restating mathematical concepts, (2) classifying objects according to their properties, (3) representing concepts in different forms, (4) applying concepts to mathematical problems, and (5) explaining relationships between mathematical concepts.

Data collection began with preliminary observation and interviews to identify learning problems and media needs. The researchers then developed the website-based gamification media according to the 4D development stages. Following expert validation and revision, the media was implemented in a limited classroom trial. Students completed a pretest before the learning intervention and a posttest after using the website-based gamification media. Teacher and student responses were collected following implementation.

Validity and practicality data were analyzed using percentage scores. The percentage was calculated by comparing the obtained score with the maximum possible score and multiplying the result by 100%. The effectiveness analysis began with descriptive statistics and a Shapiro–Wilk normality test. When the data met the normality assumption, a Paired Sample t-test was used to examine differences between pretest and posttest scores. If the normality assumption was not met, a Wilcoxon Signed Rank Test was planned as a non-parametric alternative.

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3. RESULTS AND DISCUSSION

3.1. Results

The website-based gamification media was developed through the Define, Design, Develop, and Disseminate stages. The Define stage identified students' difficulties in understanding spatial geometry and the limited availability of interactive learning media at the research school. The Design stage translated these needs into a website-based learning environment containing learning objectives, mathematical learning materials, visual illustrations, instructional videos, interactive quizzes, and gamification features.

The final product integrates learning content and game-based elements within a single website. The gamification components consist of points, badges, levels, rewards, timers, lives, and automatic feedback. These elements were incorporated into the learning activities rather than being presented as separate game features. Students are required to complete learning activities and quizzes while receiving points and other rewards based on their performance.

Table 1. Media and material validation results.

No.	Aspect	Target (%)	Category
1	Media Expert Validation	72%	Good
2	Material Expert Validation	71.6%	Good

The results indicate that the developed media met the minimum feasibility criteria established in the study. The media validation result suggests that the interface, navigation, interactivity, and technical presentation were considered appropriate, while the material validation result indicates that the mathematical content was considered suitable for the intended learning context.

During the limited implementation, students interacted with the learning materials, completed quizzes, and used the gamification features. The classroom implementation showed that students participated in learning activities and interacted with points, badges, levels, rewards, timers, lives, and automatic feedback. The teacher also reported that the visual and interactive components helped present spatial geometry concepts.

Table 2. Media effectiveness test results.

No.	Aspect	Results
1	Paired Sample t-test	Sig. < 0.05
2	N-Gain	0.6208
3	Category	Moderate

The statistical analysis showed a significant difference between students' pre-test and post-test scores ($p < 0.05$). The N-Gain value of 0.6208 indicates that students' conceptual understanding improved at a moderate level after using the website-based gamification media

3.2. Discussion

The expert validation results indicate that the website-based gamification media met the feasibility criteria established in the study. The media expert score of 72% and material expert score of 71.6% suggest that the developed product was considered suitable in terms of its instructional presentation, visual design, navigation, interactivity, and mathematical content. However, the interpretation of these percentages depends on

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the validity criteria used in the study. Therefore, the category thresholds and the corresponding source should be explicitly reported to allow readers to evaluate the meaning of the validation results.

The development of the media addressed the problem identified during the preliminary study, namely the limited availability of interactive media for teaching spatial geometry. The product combined learning materials with illustrations, instructional videos, interactive quizzes, and game-based features in one website. This combination is relevant to the characteristics of spatial geometry because students need opportunities to observe and interpret representations of three-dimensional objects. From the perspective of Multimedia Learning theory, the use of words and visual representations can support learning when the information is organized in ways that help students select and integrate relevant information (Mayer, 2020). Thus, the multimedia components of the developed media were intended not merely to make the interface attractive but to provide additional representations of mathematical ideas.

The potential contribution of the interactive visualizations can also be understood through the nature of spatial geometry itself. Spatial geometry contains concepts that may be difficult for elementary students to understand when presented only through verbal explanations or static textbook illustrations. Visual representations and interactive activities may provide students with opportunities to connect mathematical terms with observable characteristics of geometric objects. This mechanism may help reduce the distance between abstract mathematical concepts and students' concrete learning experiences.

The gamification features provide another mechanism through which the media may support learning. Points, badges, levels, rewards, timers, and lives establish short-term goals and provide feedback during learning activities. Rather than assuming that gamification directly improves conceptual understanding, the more reasonable interpretation is that these elements may increase students' engagement with learning tasks. Greater engagement can create more opportunities for students to interact with learning materials, attempt problems, receive feedback, and revise their responses. Previous studies have similarly reported that gamification can support student motivation and participation in mathematics learning (Irnawati et al., 2024; Jutin & Maat, 2024; Valentinna et al., 2024).

Automatic feedback is particularly relevant to conceptual learning because it allows students to recognize whether their responses are correct and to reconsider incorrect answers. When feedback is provided immediately after an activity, students have an opportunity to identify errors while the relevant concept is still active in their working memory. In the present media, automatic feedback was integrated with quizzes and game-based activities. This feature therefore provides a mechanism through which students can repeatedly practice applying spatial geometry concepts.

The N-Gain value of 0.6208 indicates a moderate level of improvement in students' scores. The significant result of the Paired Sample t-test further indicates that the difference between pretest and posttest scores was statistically significant. These findings are consistent with the purpose of the developed media, which was to provide a more interactive environment for learning spatial geometry. Nevertheless, the statistical result should not be interpreted as conclusive evidence that the media alone caused the improvement. The study used a one-group pretest–posttest design involving 26 students and did not include a control group. Therefore, factors such as repeated exposure to the test, classroom instruction, practice effects, maturation, and other learning experiences may also have contributed to the observed change

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4. CONCLUSION

This study developed website-based gamification media for fourth-grade students' mathematics learning on spatial geometry using the Four-D development model. The developed media integrates learning materials, visual illustrations, instructional videos, interactive quizzes, and gamification elements, including points, badges, levels, rewards, timers, lives, and automatic feedback.

The expert validation results were 72% for the media aspect and 71.6% for the material aspect, both categorized as good based on the criteria used in the study. The effectiveness analysis showed a significant difference between students' pretest and posttest scores ($p < 0.05$), while the N-Gain value of 0.6208 was classified as moderate. These results indicate an improvement in students' mathematical conceptual understanding following the implementation of the developed media.

However, the findings should be interpreted cautiously because the study involved only 26 students from one class at one elementary school and employed a one-group pretest–posttest design without a control group. Therefore, the improvement cannot be attributed exclusively to the developed media. The findings instead indicate that the website-based gamification media has potential to support students' mathematical conceptual understanding through interactive multimedia, repeated learning activities, and immediate feedback.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirm that this manuscript is free of plagiarism.

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