

THE IMPACT OF GAMIFICATION BASED INTERACTIVE SCIENCE LEARNING MEDIA ON STUDENT ENGAGEMENT AND PROBLEM SOLVING SKILLS AMONG ELEMENTARY SCHOOL STUDENTS

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This study aims to develop valid, practical, and effective gamification-based interactive science learning media using the Wordwall platform to enhance elementary school students' engagement and problem-solving skills. Employing a Research and Development (R&D) approach, this research combined the ADDIE model with a pre-experimental One-Group Pretest-Posttest Design at SD Negeri 060970 Medan Belawan during the even semester of the 2025/2026 academic year, involving 25 fourth-grade students. Data were collected using expert validation sheets, teacher and student response questionnaires, learning observation sheets, and essay tests. Expert validation confirmed the media's high validity, scoring 89.60% from material experts and 92.30% from media experts. Practicality assessments reached 92.66% from teachers and 87.06% from students. Cognitive test results showed a significant increase from a pretest mean of 60.94 to a posttest mean of 83.11 (a 36.4% gain), supported by a paired sample t-test ($t = 20.15$, $p = 0.000 < 0.05$), a moderate average N-Gain score of 0.57, and an increase in active student engagement from 62% to 88%. Consequently, Wordwall-based learning media is valid, practical, and effective for elementary science education.

Keywords: Gamification, Wordwall, Student Engagement, Problem-Solving, SDN 060970 Medan Belawan

INTRODUCTION

Natural Science (IPA) education in elementary schools is targeted to instill scientific literacy skills, science process skills, and the ability to solve everyday life problems (Sari & Wulandari, 2023). However, the reality of science learning in elementary classrooms currently faces serious challenges due to the dominance of conventional, one-way teaching methods. Monotonous learning causes elementary school students to be less actively involved, which results in low cognitive and emotional student engagement, as well as weak reasoning skills in solving contextual problems (Febrina et al., 2024). At SD

Negeri 060970 Medan Belawan, located in the coastal area of Belawan, the limited availability of interactive digital learning media is one of the main factors hindering the achievement of learning competencies among Grade IV students, who frequently complain that science content is overly abstract and theoretically dense.

As digital natives, 21st-century elementary school students require learning tools that are interactive, contextual, and cognitively challenging (Alimuddin et al., 2023). One innovation that can bridge this challenge is the gamification approach. Gamification adopts digital game elements such as point systems, leveled challenges, instant feedback, and leaderboards into non-game academic contexts to boost students' intrinsic motivation and learning focus (Sappaile, 2024). The Wordwall platform is a highly potential digital interactive medium because it provides a wide variety of gamified science learning activity formats, ranging from random quizzes and spinning wheels to card matching and maze chases that align with the characteristics of primary school-age children.

Research on gamification in education continues to grow rapidly. Several previous studies have mapped the utilization of similar digital media, such as the use of Kahoot games for evaluating learning outcomes in Buddhist Religious Education (Putra et al., 2026), the development of QuizWhizzer-based interactive learning media for elementary mathematics (Laela & Sunanto, 2025), and the implementation of the Problem-Based Learning (PBL)

model assisted by gamified flashcards on junior high school science problem-solving (Khaer et al., 2026). In addition, research on the utilization of Visual-Auditory-Kinesthetic (VAK)-based animated videos has also proven its significance in minimizing students' abstract cognitive load (Ramadhani & Handoyo, 2026). However, most of these gamification studies remain partial because they solely focus their analysis on the domain of intrinsic motivation, without simultaneously examining student engagement (cognitive, affective, and behavioral) and its impact on students' problem-solving abilities.

Therefore, the originality and novelty of this study lie in the development of Wordwall media specifically integrated with the science curricular needs of Grade IV at SD Negeri 060970 Medan Belawan. In this research, student engagement is positioned as a key variable (mediator) that is comprehensively measured and directly linked to the acceleration of students' elementary science problem-solving skills. This study seeks to address this research gap by providing a concrete solution in the form of gamification-based interactive science learning media that is valid, practical, and empirically proven to be effective.

METHOD

This study applies the Research and Development (R&D) method utilizing the ADDIE procedural development model developed by Ayu Triputri Br. Samosir and Syahmi Edi (2026), which encompasses five structured phases: (1) *Analysis*, or the initial analysis of needs, curriculum, and the characteristics of Grade IV students at SDN 060970 Medan Belawan; (2) *Design*, or the initial drafting of the media, formulation of Wordwall gamification quizzes, and construction of test blueprints; (3) *Development*, or media production followed by feasibility validation testing by subject-matter and media design experts; (4) *Implementation*, or field trials to assess the practicality and effectiveness of the media; and (5) *Evaluation*, or the summative evaluation of the entire development process. The field trial was conducted at SD Negeri 060970 Medan Belawan, Medan Belawan District, Medan City, North Sumatra Province, during the even semester of the 2025/2026 academic year. Because the school has only a single class for the Grade IV level, the media effectiveness testing did not employ a quasi-experiment with a separate control group, but instead utilized a pre-experimental quantitative approach through a One-Group Pretest-Posttest Design. The research subjects (sample) comprised the entire Grade IV population of 25 students (total sampling), consisting of 12 male students and 13 female students. Data collection techniques employed expert validation assessment sheets, teacher and student practicality response questionnaires, as well as written tests consisting of science problem-solving essay questions for the pretest and posttest.

Content validity data analysis referred to the feasibility scores provided by subject-matter and media experts. Media practicality was derived from the percentage scores obtained from the classroom teacher and student response questionnaires. Cognitive effectiveness analysis was measured by calculating the difference in mean scores, conducting a paired samples t-test hypothesis test using IBM SPSS Statistics version 25 to examine the significance of differences before and after the intervention, and calculating the N-Gain Score to determine the level of improvement in Grade IV students' science problem-solving abilities after utilizing Wordwall.

RESULTS AND DISCUSSION

Based on the development stages conducted, the developed Wordwall interactive science learning media successfully passed the feasibility and practicality tests prior to being trialed on Grade IV subjects. The feasibility of the draft media was evaluated by subject-matter and media validators, whereas practicality was obtained from the responses of the science classroom teacher and questionnaires from 25 Grade IV students. The summary of validity and practicality results is presented in Table 1.

Table 1. Feasibility and Practicality Results of Wordwall Media

No.	Assessment Aspect	Score (%)	Feasibility / Practicality Category
1	Subject-Matter Expert Validation (Feasibility)	89.60%	Highly Feasible / Highly Valid
2	Media Expert Validation (Feasibility)	92.30%	Highly Feasible / Highly Valid
3	Classroom Teacher Practicality Response	92.66%	Highly Practical
4	Practicality Response of 25 Grade IV Students	87.06%	Highly Practical

The recapitulation results in Table 1 confirm that the developed Wordwall science learning media meets the qualifications of being highly valid and highly practical for instructional use. The subject-matter expert rating of 89.60% indicates the alignment of contextual science content with the elementary school curriculum, while the media expert rating of 92.30% demonstrates that Wordwall's visual interface, audio elements, and interactive buttons are highly child-friendly. The practicality scores of 92.66% from the science classroom teacher and 87.06% from the 25 Grade IV students prove that this medium is not only easy to operate but also highly engaging for children.

The cognitive effectiveness of the interactive Wordwall media on students' problem-solving abilities was analyzed by comparing the mean scores of the pretest (prior to intervention) and posttest (after gamification-based learning). A summary of descriptive statistics for the pretest and posttest across the 25 Grade IV students is presented in Table 2.

Table 2. Summary of Pretest-Posttest Score Analysis Results

Measurement Parameter	Pretest (Before Wordwall)	Posttest (After Wordwall)
Sample Size (<i>N</i>)	25 Students	25 Students
Mean Score	60.94	83.11
Minimum Score	50.00	74.00
Maximum Score	70.00	88.00
Standard Deviation (<i>SD</i>)	4.78	2.95

The data in Table 2 indicate a substantial improvement in the science problem-solving abilities of Grade IV students. The students' mean score increased by 22.17 points (from 60.94 to 83.11) following regular interactive trials with Wordwall, representing a 36.4% gain in learning outcomes. The lower standard deviation on the posttest (2.95) compared to the pretest (4.78) demonstrates that the distribution of students' scores became more homogeneous and evenly distributed following the intervention.

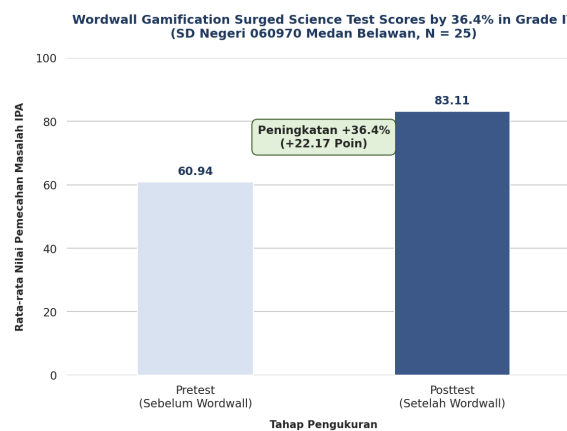


Figure 1. Comparison Chart of Grade IV Pretest and Posttest Scores

To statistically verify the significance of this mean difference using parametric analysis, a prerequisite Shapiro-Wilk normality test was performed using SPSS version 25. The test results yielded a significance value (*p*-value) of 0.488 for the pretest and 0.249 for the posttest. Because both significance values are well above the significance threshold of $\alpha = 0.05$, it can be conclusively determined that the distribution of pretest and posttest score data is normally distributed.

After fulfilling the assumption of normality, hypothesis testing was conducted using a Paired Sample *t*-Test. The SPSS data analysis produced a calculated *t*-value (t_{count}) of 20.15 with 24 degrees of freedom (*df*) and a significance level (*p*-value) of 0.000. Because the *p*-value of $0.000 < 0.05$, the null hypothesis (H_0) is decisively rejected and the alternative hypothesis (H_a) is accepted. These inferential statistical findings empirically prove that the gamification-based Wordwall interactive science learning media intervention exerts a highly significant effect on enhancing the science problem-solving abilities of Grade IV students at SDN 060970 Medan Belawan.

The magnitude of this improvement was further evaluated using the Normalized Gain (N-Gain) Score test. The calculation revealed an average N-Gain Score of 0.57 among Grade IV students, falling into the Moderate category. In addition to cognitive gains, classroom observation sheets documented a remarkable increase in active student engagement, where the average emotional, cognitive, and behavioral engagement of students initially measured at 62% during the pretest phase surged to 88% by the final evaluation session.

Furthermore, to test the significance level of the mean differences, a Shapiro-Wilk distribution normality test was conducted. Based on SPSS statistical analysis, the significance values (p -value) obtained were 0.488 for the pretest and 0.249 for the posttest. Because both values are well above the 0.05 significance level, it can be stated with confidence that the data are normally distributed. Parametric testing using a Paired Sample t -Test yielded a t -value of 20.15 with 24 degrees of freedom (df) and a significance p -value of 0.000. Because the p -value is $0.000 < 0.05$, the null hypothesis (H_0) is firmly rejected, proving that the gamification-based Wordwall interactive science learning media intervention has a highly significant effect on boosting students' science capabilities.

This level of effectiveness is also evidenced by the average N-Gain score of 0.57, which is categorized as Moderate. The enhancement of students' cognitive skills was accompanied by strengthening in their affective and behavioral domains in the classroom. Structured observation results recorded an increase in the average level of active student engagement from 62% at the beginning of the intervention to 88% at the final session.

DISCUSSION

The research findings demonstrate that the development of gamification-based science learning media using the Wordwall platform exerts a highly significant positive impact on student engagement and the problem-solving abilities of Grade IV students at SD Negeri 060970 Medan Belawan. The high feasibility scores for instructional content (89.60%) and media design (92.30%) indicate that the instructional design of this media has satisfied theoretical and practical feasibility standards. This finding aligns with other digital educational media R&D studies (Samosir & Edi, 2026; Laela & Sunanto, 2025; Mulyati & Supardi, 2025). Reducing interface complexity and presenting contextual science content familiar to coastal children in Medan Belawan has proven effective in minimizing usability barriers for early and elementary grade students (Artini, 2025). The responses from the teacher (92.66%) and students (87.06%), categorized as highly practical, further reinforce that Wordwall media is easy for children to operate independently and assists elementary school teachers in visualizing science concepts that are typically difficult to reason through verbally.

Students' cognitive improvement, evidenced by the increase in the mean score from pretest to posttest (from 60.94 to 83.11, $t_{\text{count}} = 20.15$, $p\text{-value} = 0.000$), demonstrates the effectiveness of Wordwall as an interactive evaluation instrument. The N-Gain score of 0.57, which falls into the Moderate category, is consistent with other digital interactive gamification studies such as the QuizWhizzer platform (Laela & Sunanto, 2025) and Kahoot (Putra et al., 2026), as well as the use of gamification-based flashcards in basic science (Khaer et al., 2026). Although the pre-experimental One-Group Pretest-Posttest Design lacks a comparative control group meaning that the surge in cognitive learning outcomes cannot be 100% purely attributed to the media intervention alone and could potentially be influenced by the testing effect and novelty effect (Putra et al., 2026; Samosir & Edi, 2026) the substantial t_{count} value (20.15) significantly exceeding the critical t_{table} value firmly reaffirms the efficacy of Wordwall media in assessing and reinforcing Grade IV students' understanding of basic science concepts.

The acceleration of student engagement (from an average of 62% to 88%) can be comprehensively explained through Self-Determination Theory (SDT) developed by Ryan & Deci (2023). The Wordwall platform successfully facilitates three basic psychological needs of elementary school Grade IV students: autonomy, competence, and relatedness (Ryan & Deci, 2023). The need for autonomy is fulfilled when students are granted the freedom to choose their quiz paths or select interactive quiz visualization formats. The need for competence is directly met as the platform delivers instant feedback in the form of 'correct/incorrect' sound effects, point systems, stars, and automatically dynamic leaderboard visualizations. Meanwhile, the need for relatedness is fostered because, although activities are carried out individually, the scores recorded on the leaderboard trigger healthy collaborative discussions and positive competitive benchmarking among peers in the classroom. Satisfying these three basic needs transforms students' motivational orientation from initially extrinsic (fear of teacher reprimand or merely chasing grades) into stable intrinsic motivation (genuine interest stemming from enjoying the scientific process) (Sappaile, 2024).

In addition, the sustained attention of Grade IV students while engaging with Wordwall quizzes is corroborated by Flow Theory from Csikszentmihalyi, (1990). From the perspective of this theory, student engagement reaches its peak (a state of flow) when the challenge level presented by the game is precisely balanced with the student's cognitive ability or thinking skill level (Csikszentmihalyi, 1990). The interactive Wordwall

quizzes, designed with time limits (timers) and tiered difficulty levels, prevent students from slipping into the anxiety zone (which occurs when material is overly complex) or the boredom zone (which occurs when material is overly monotonous). The total immersion generated within this flow state alleviates science anxiety previously experienced by students due to rigid instructional methods, enabling elementary school students to feel relaxed while maintaining high reasoning acuity when solving problem-solving tasks.

From the perspective of Cognitive Load Theory (CLT) (Mayer, 2023), the Wordwall media innovation optimizes Grade IV students' working memory capacity by managing cognitive load. Conventional lecture-based basic science instruction frequently overburdens elementary students' working memory with excessive extraneous cognitive load resulting from abstract presentations of information. Wordwall interactive media presents visually structured information coupled with dynamic audio-visual elements (multimedia scaffolding). This significantly reduces extraneous cognitive load and enhances germane cognitive load, which is essential for deep processing (Mayer, 2023). Consequently, students' limited mental capacity can be entirely channeled into constructing robust cognitive mental schemas and fostering long-term memory retention of basic science principles, aligning with findings on VAK media by Ramadhani & Handoyo (2026) and cognitive concept visualization by Sari & Wulandari (2023).

Finally, the successful implementation of Wordwall at SD Negeri 060970 Medan Belawan provides a significant practical contribution to the development of elementary school teachers' Technological Pedagogical Content Knowledge (TPACK), particularly in coastal or marginal areas (Dekar et al., 2024, Dekar et al., 2026). The utilization of digital media aligned with the science curriculum demonstrates that infrastructural constraints in the coastal region of Belawan do not pose an insurmountable barrier to implementing student-centered, interactive digital learning. The findings of this study serve as an empirical foundation for elementary education digitalization initiatives in Indonesia to narrow the science education quality gap between urban and coastal regions, in line with the 21st-century educational roadmap (Alimuddin et al., 2023).

The results of this study also demonstrate that the implementation of Kahoot game-based interactive learning media is proven effective in improving the Buddhist Religious Education learning outcomes of Grade X students at SMK Cluwak. This result is based on significant findings during data analysis, where there was a notable increase in students' mean score, rising from 57 on the pretest to 80 on the posttest. The highest score achieved by students after receiving the treatment increased to a perfect score of 100, while the lowest score rose from 30 to 45. These findings are reinforced by prerequisite analytical testing, in which the pretest ($p = 0.377$) and posttest ($p = 0.120$) data distributions proved to be normally distributed because their significance values exceeded 0.05, and exhibited a linear relationship with a deviation from linearity significance value of 0.900. Systematically, these figures reflect significant cognitive changes that are not coincidental, but rather the direct result of the innovative learning media intervention.

CONCLUSION

The development of the gamification-based interactive science learning media innovation using the Wordwall platform is declared highly valid (subject-matter feasibility score of 89.60%; media design of 92.30%), highly practical (classroom teacher response of 92.66%; student response of 87.06%), and highly effective in enhancing student engagement and problem-solving skills among Grade IV students at SD Negeri 060970 Medan Belawan. These empirical findings are evidenced by an increase in the mean score from 60.94 on the pretest to 83.11 on the posttest (a 36.4% gain), validated through a paired sample t -test (p -value = 0.000 < 0.05; $t_{\text{count}} = 20.15$), an average N-Gain score in the moderate category (0.57), and a surge in active student engagement reaching an average of 88%.

Based on the data analysis and in-depth theoretical discussion, it is concluded that the gamification-based interactive science learning media using Wordwall fulfills the instructional expectations outlined in the introductory framework. The detailed empirical conclusions are summarized as follows:

1. Exceptionally High Theoretical Feasibility: Wordwall media has proven to be theoretically valid and feasible based on evaluations by subject-matter experts scoring 89.60% (encompassing cognitive curriculum alignment, depth of science content, and linguistic appropriateness) and media experts scoring 92.30% (encompassing typographic readability, layout clarity, visual harmony, and digital design usability).
2. Outstanding Operational Practicality: The media is categorized as highly practical for classroom implementation, as demonstrated by the science teacher's response score of 92.66% (ease of use, language, interface presentation, and time efficiency) and the psychological satisfaction rating of 87.06% from the 25 Grade IV students (media attractiveness, presentation clarity, and learning utility).

3. Significant Cognitive and Affective Effectiveness: Effectiveness testing confirms that Wordwall substantially enhances cognitive outcomes and active student participation. The students' mean problem-solving score rose sharply by 22.17 points (a 36.4% increase from 60.94 to 83.11). This difference is statistically significant according to the paired samples *t*-test ($t_{\text{count}} = 20.15$, $df = 24$, $p\text{-value} = 0.000 < 0.05$) and is reinforced by an average N-Gain score of 0.57 (Moderate category). Concurrently, active student engagement recorded a marked increase from 62% prior to the intervention to 88% at the post-intervention stage.

Theoretically, the novelty of this research demonstrates that student engagement serves as a decisive mediator in stimulating elementary science problem-solving capabilities. Integrating interactive visual scaffolding and dynamic gamification mechanics on the Wordwall platform effectively bridges students' cognitive barriers when confronting abstract concepts and systematically eliminates learning fatigue.

For future development plans and broader service implementation, this gamification model can be scaled and adapted across other elementary science topics and integrated into teacher professional development programs (TPACK workshops), providing sustainable digital instructional solutions particularly for coastal and resource-constrained educational environments.

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