JPPIPA 12(8) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Effect of Wordwall-Based Differentiated Instruction on Elementary Students' Science Achievement and Attention toward Quality Education

Monica Dina Candra Riani*, Joko Sulianto[1], Achmad Buchori[1]

[1]Master of Elementary Education, Graduate School, Universitas PGRI Semarang (UPGRIS), Semarang, Indonesia.

Received: June 23, 2026
Revised: August 10, 2026
Accepted: August 28, 2026
Published: August 31, 2026

Corresponding Author:
Monica Dina Candra Riani
monique.li3m@gmail.com

DOI: 10.29303/jppipa.v12i8.15820

Abstract: An instructional innovation integrating Wordwall-assisted differentiated instruction was implemented to examine its effectiveness in improving elementary students' science learning outcomes. A quasi-experimental pretest–posttest control group design was employed involving 32 sixth-grade students, with 16 students assigned to the experimental group and 16 students to the control group. Data were collected using a standardized science learning outcomes test administered before and after the intervention. Descriptive statistics were used to summarize students' performance, while the assumptions of normality and homogeneity were examined prior to hypothesis testing. An independent-samples t-test was conducted to compare the posttest scores of the experimental and control groups, and Cohen's d was calculated to estimate the practical significance of the intervention. The findings demonstrated a statistically significant difference in posttest science learning outcomes between the two groups ($p < .05$), with students receiving Wordwall-assisted differentiated instruction achieving higher posttest scores than those taught using the Drill and Practice method. Furthermore, the intervention produced a large effect size ($d = 0.92$), indicating substantial practical significance in enhancing students' science learning outcomes. These findings suggest that integrating Wordwall into differentiated instruction provides an effective approach for improving science learning in elementary schools and supports the achievement of Sustainable Development Goal 4 by promoting inclusive, engaging, and high-quality education.

Keywords: Differentiated instruction; Elementary science; Wordwall; Wordwall-based learning

Introduction

Improving the quality of human resources and preparing students for 21st-century competencies have become essential priorities in modern education systems. In Indonesia, the implementation of the Merdeka Curriculum emphasizes student-centered learning, meaningful learning experiences, and the integration of digital technology to support active and independent learning (Halim et al., 2024). Recent studies also indicate that the Merdeka Curriculum encourages differentiated instruction and technology-supported assessment to accommodate students' diverse learning needs and improve learning quality (Asnawi et al., 2023). At the elementary level, Natural and Social Sciences (IPAS) aims to develop students' conceptual understanding through contextual, inquiry-based, and interactive learning processes. Therefore, instructional strategies that actively engage students cognitively and behaviorally are increasingly required to achieve meaningful learning outcomes (Aulia et al., 2023).

Despite these expectations, science learning in elementary schools remains challenging, particularly in abstract topics such as the solar system. Several empirical studies report that students still experience low achievement, passive participation, and limited

How to Cite:
Riani, M. D. C., Sulianto, J., & Buchori, A. (2026). Effect of Wordwall-Based Differentiated Instruction on Elementary Students' Science Achievement and Attention toward Quality Education. *Jurnal Penelitian Pendidikan IPA*, *12*(8), 152–163. https://doi.org/10.29303/jppipa.v12i8.15820

engagement in science learning activities (Asipi et al., 2022). Similar findings have also been reported in Indonesian science classrooms, where students encounter conceptual misconceptions, limited scientific literacy, and insufficient classroom interaction (Julianto et al., 2023). Preliminary observations conducted in Grade VI classrooms in Bogorejo District, Blora Regency, further revealed that only 43% of students achieved the Minimum Mastery Criterion (KKM) in the Solar System topic, while 57% failed to reach the expected competency level. Classroom observations also indicated that more than half of the students were passive during science instruction, and interviews with teachers revealed that learning activities were still predominantly teacher-centered with limited use of interactive digital media (Getenet & Tualaulelei, 2023). These findings demonstrate the urgent need for innovative instructional approaches that actively involve students and facilitate meaningful conceptual understanding (Flegr et al., 2023).

To address these challenges, differentiated instruction has been widely recognized as an effective pedagogical approach. This approach enables teachers to modify content, learning processes, and learning products according to students' readiness, interests, and learning profiles (Witraguna et al., 2024). Recent studies have demonstrated that differentiated instruction creates more inclusive learning environments and facilitates personalized learning experiences through adaptive teaching strategies and digital diagnostic assessment (Napitupulu et al., 2023). Consequently, differentiated instruction is considered one of the most appropriate approaches for implementing the principles of the Merdeka Curriculum in elementary science classrooms.

In technology-enhanced learning environments, differentiated instruction can be further strengthened through interactive digital platforms such as Wordwall. Wordwall provides game-based learning features, including quizzes, matching activities, visual games, and interactive exercises that help students understand abstract scientific concepts through enjoyable learning experiences. Previous studies have demonstrated that Wordwall improves students' motivation, participation, and academic achievement (Agustina et al., 2025). Likewise, technology-assisted assessment and interactive digital learning media have been shown to increase classroom interaction, provide immediate feedback, and promote active learning (Lestari, 2023). Furthermore, game-based digital learning environments have been found to enhance students' conceptual understanding and sustain learning engagement by creating enjoyable and meaningful instructional experiences (Siami et al., 2023). These findings suggest that integrating Wordwall into differentiated instruction has strong potential to improve both students' cognitive performance and classroom engagement.

From a theoretical perspective, this study is grounded in Tomlinson's Differentiated Instruction Theory, Constructivist Learning Theory, and Cognitive Engagement Theory. According to Tomlinson, effective instruction should accommodate differences in students' readiness, interests, and learning profiles through adaptive teaching strategies. Constructivist Learning Theory explains that meaningful learning occurs when students actively construct knowledge through interaction with learning experiences rather than passively receiving information (Hidayati & Eriyanti, 2023). Meanwhile, Cognitive Engagement Theory emphasizes that students' attention, cognitive effort, and active participation are fundamental determinants of successful learning. Therefore, integrating differentiated instruction with Wordwall-based digital learning is theoretically expected to facilitate active knowledge construction while simultaneously increasing students' attention, engagement, and science learning achievement (Nur et al., 2023).

Although previous studies have investigated differentiated instruction, technology-assisted assessment (interactive digital learning, science literacy, and technology-supported learning media (Siami et al., 2023) no previous study has simultaneously examined the effectiveness of Wordwall-based differentiated instruction on both science achievement and student attention among elementary school students within the context of the Merdeka Curriculum. Most previous studies focused only on cognitive achievement or learning motivation separately, without investigating how differentiated digital instruction influences students' attention as an essential component of cognitive engagement (Ridwan et al., 2023). Consequently, empirical evidence regarding the simultaneous improvement of science achievement and student attention through differentiated Wordwall-based instruction remains limited.

Student attention constitutes a critical aspect of cognitive engagement because it reflects learners' ability to maintain concentration, process information effectively, and actively participates during classroom instruction. Higher levels of attention enable students to understand scientific concepts more deeply and retain learning experiences more effectively (Darmawan et al., 2025). Previous studies have reported that interactive digital learning environments increase students' engagement and conceptual understanding; however, evidence specifically examining student attention within differentiated digital instruction remains scarce, particularly in Indonesian elementary science education (Dayanti et al., 2023).

Therefore, this study addresses these research gaps by investigating the effect of Wordwall-based differentiated instruction on elementary students' science achievement and attention. This study differs from previous research in three important respects (Hamidah et al., 2023). First, it integrates differentiated instruction with Wordwall-based game learning within a single instructional framework. Second, it simultaneously examines two dependent variables, namely science achievement and student attention, to provide a more comprehensive evaluation of instructional effectiveness (Dewi et al., 2024). Third, the study is conducted in elementary IPAS learning under the implementation of the Merdeka Curriculum, thereby providing empirical evidence regarding the effectiveness of technology-enhanced differentiated instruction in authentic classroom settings (Kharisma et al., 2023). These contributions are expected to enrich the literature on differentiated digital learning and provide practical implications for improving elementary science instruction in Indonesia.

Method

A quasi-experimental approach using a pretest–posttest control group design was employed to examine the causal effect of the instructional intervention on students' learning outcomes. This design is classified as experimental research because it aims to establish causal relationships between instructional strategies and changes in students' academic performance by comparing outcomes between experimental and control groups while controlling for baseline differences (Creswell & Creswell, 2023). The pretest–posttest control group design is widely recommended in educational research because it provides a rigorous framework for evaluating the effectiveness of instructional interventions implemented under authentic classroom conditions (Nasution & Suyanto, 2023).

The experimental group received Wordwall-based differentiated instruction, whereas the control group was taught using the conventional drill-and-practice approach. Both groups completed pretests before the intervention and posttests after the intervention to determine differences in science achievement and student attention attributable to the instructional treatment (Sunarti et al., 2023). Similar quasi-experimental designs have frequently been employed to evaluate the effectiveness of innovative instructional models and technology-enhanced learning media in elementary education (Anwar et al., 2024).

This methodological framework enables the investigation of instructional effectiveness under authentic classroom conditions while allowing valid comparisons between the experimental and control groups. Consequently, the selected design is appropriate for determining the effectiveness of Wordwall-based differentiated instruction in improving elementary students' science achievement and student attention, while providing stronger evidence regarding the causal impact of the instructional intervention (Istiqomah & Wibowo, 2024).

Variables of the Study

The research framework involved four interrelated variables, consisting of one independent variable, one main dependent variable. Wordwall-assisted differentiated instruction served as the independent variable representing the instructional treatment applied in the experimental classroom (Meutstege & Geel, 2023). Science learning outcomes on the solar system topic functioned as the primary dependent variable, reflecting students' cognitive achievement after the learning intervention (Rönn-liljenfeldt et al., 2024).

Student attention refers to the extent of learners' behavioral and cognitive engagement during classroom activities, which can be observed through sustained focus, active participation, responsiveness to instructional tasks, and consistency in completing learning activities throughout the lesson.

Table 1. Variables of the study

Variable Type	Variable	Role in Study
Independent Variable	Wordwall-assisted differentiated instruction	Instructional treatment
Dependent Variable	Science learning outcomes	Learning achievement

Table 1 summarizes the variables investigated in this study. Wordwall-assisted differentiated instruction functions as the independent variable, science learning outcomes represent the dependent variable, and examine its potential contribution to students' learning achievement.

Research Design

Investigating the effectiveness of Wordwall-based differentiated instruction required a research design capable of comparing learning progress while accommodating the practical constraints of classroom-based research. For this reason, a quasi-experimental pretest–posttest control group design was selected, as it allows instructional interventions to be implemented in naturally existing classes without random assignment while still providing a reasonable basis for estimating treatment effects through comparisons between groups (Reichardt et al., 2023). Recording students' achievement before and after the intervention further enables changes in learning performance to be examined relative to their

initial competence, thereby strengthening the evaluation of instructional effectiveness (Fraenkel et al., 2023). The experimental research design adopted in this study is presented in Table 2.

Table 2. Pretest–posttest control group experimental design (Fabrigar et al., 2024)

Group	Pretest	Treatment	Posttest
Experimental	O_1	Wordwall-assisted differentiated instruction	O_2
Control	O_3	Drill and Practice (Conventional Learning)	O_4

O_1 and O_3 denote the pretest, O_2 and O_4 denote the posttest. The experimental group received Wordwall-assisted differentiated instruction, whereas the control group received Drill and Practice (conventional learning).

Population and Sample

The study involved 32 sixth-grade students from two elementary schools in the Madukoro Cluster, Central Java, Indonesia. Participants were assigned into two intact classroom groups, comprising an experimental group (n = 16) and a control group (n = 16). The experimental group received Wordwall-based differentiated instruction, whereas the control group was taught using the conventional Drill-and-Practice approach. The schools were selected through purposive sampling based on predefined criteria, including implementation of the Merdeka Curriculum for at least one academic year and teachers' readiness to implement differentiated instructional practices. The use of intact classrooms is consistent with the characteristics of quasi-experimental research, where random assignment is generally not feasible in authentic educational settings.

To ensure comparability between groups, pretest scores were analyzed to establish baseline equivalence before the intervention. The effectiveness of the instructional intervention was subsequently evaluated using hypothesis testing and effect size analysis to determine both the statistical significance and practical magnitude of the treatment effect. Ethical approval was obtained from the participating school principals and classroom teachers prior to data collection. Student participation was voluntary, and all research data were treated confidentially in accordance with established ethical guidelines (Tajik et al., 2024).

Although the relatively small sample size may limit the generalizability of the findings, it is considered appropriate for evaluating the preliminary effectiveness of instructional interventions in classroom-based quasi-experimental research. Accordingly, the results, particularly those derived from regression analysis, should be interpreted as exploratory rather than conclusive.

Research Procedure

The research procedure consisted of three sequential phases: preparation, implementation, and post-implementation.

During the preparation phase, classroom observations were conducted to identify students' learning difficulties and existing instructional practices in Natural and Social Sciences (IPAS), particularly on the Solar System topic. Subsequently, all research instruments, including the science achievement test, student attention questionnaire, observation sheet, and lesson plans, were validated by experts to ensure their content validity, clarity, and appropriateness before implementation.

During the implementation phase, the intervention was conducted over four instructional meetings, each lasting approximately 70 minutes. The experimental group received Wordwall-based differentiated instruction, whereas the control group received the conventional Drill-and-Practice approach. The teacher facilitated learning by adapting instructional content, learning processes, and student tasks according to students' readiness levels. The Wordwall platform was used to support interactive quizzes, matching activities, and game-based learning experiences that promoted active participation and engagement.

During the post-implementation phase, both groups completed the science achievement posttest and the student attention questionnaire. The collected data were subsequently analyzed using descriptive and inferential statistical analyses to determine the effectiveness of the intervention.

Figure 1 illustrates the overall research procedure adopted in this quasi-experimental study. Both groups completed a pretest before receiving different instructional treatments. The experimental group was taught through Wordwall-based differentiated instruction, whereas the control group received conventional Drill-and-Practice instruction. Following the intervention, students completed a posttest and a Student Attention Questionnaire, and the resulting data were analyzed using t-test, N-gain, and regression analyses to determine the effectiveness of the intervention.

The overall research procedure is presented in Figure 1, while the detailed instructional activities conducted during each meeting are summarized in Table 3.

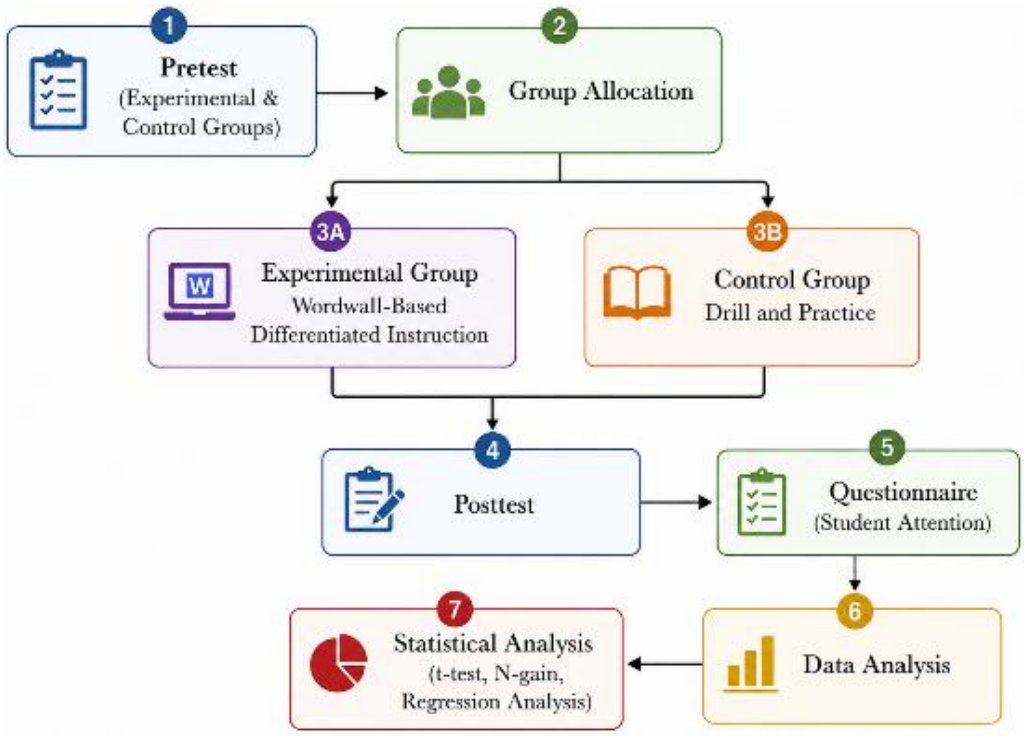

Figure 1. Research procedure of the quasi-experimental study

Result and Discussion

Result

Table 3. Implementation of Wordwall-Based Differentiated Instruction

Learning Focus	Differentiated Instruction	Wordwall Activity	Expected Learning Outcome
Pretest and Introduction to the Solar System	Diagnostic assessment and flexible grouping based on students' readiness	Quiz	Students' readiness identified and baseline science achievement established
Planet Characteristics	Differentiated Content tailored to students' readiness levels	Matching Pairs, Quiz	Improved conceptual understanding of Solar System concepts
Solar System Problem Solving	Differentiated Process through collaborative inquiry and interactive learning	Gameshow Quiz, Random Wheel	Increased student attention, participation, and engagement during learning
Review, Reflection, and Evaluation	Differentiated Product through formative assessment and reflection	Interactive Quiz	Improved science achievement and evaluation of learning outcomes

Table 3 summarizes the implementation of Wordwall-based differentiated instruction across four instructional sessions. The intervention was designed by adapting learning content, process, and product according to students' readiness levels while integrating interactive Wordwall activities to facilitate meaningful learning experiences. This instructional sequence was expected to improve students' science achievement and student attention through active participation, immediate feedback, and differentiated learning experiences.

Data Collection Techniques

Data were collected using science achievement tests, a student attention questionnaire, classroom observations, and documentation. The science achievement test consisted of pretests and posttests to measure students' learning outcomes on the Solar System topic, while the student attention questionnaire assessed students' attention during the implementation of Wordwall-based differentiated instruction (Folwell et al., 2025). Classroom observations and documentation were used to support and triangulate the research findings.

All research instruments were validated through expert judgment and tested for validity and reliability before implementation. The results indicated that the instruments were valid and reliable for use in this study research (Karimian & Chahartangi, 2024).

Data were analyzed using descriptive and inferential statistics. Descriptive statistics included the

mean, standard deviation, minimum, and maximum scores. Prior to hypothesis testing, the assumptions of normality and homogeneity were examined using the Shapiro–Wilk and Levene's tests, respectively (LeChasseur, 2024). Differences between groups were analyzed using an independent-samples *t*-test, while learning improvement within each group was examined using a paired-samples *t*-test. The effectiveness of the intervention was further evaluated using N-gain analysis, and the relationship between student attention and science achievement was analyzed using simple linear regression. All statistical tests were conducted at a 5% significance level ($\alpha = 0.05$) (Tran & Nagirikandalage, 2025).

Research Instruments

Three instruments were employed in this study: a Science Achievement Test; a Student Attention Questionnaire; and a Classroom Observation Sheet. The Science Achievement Test consisted of 20 multiple-choice items developed based on the Grade VI IPAS Learning Outcomes of the Merdeka Curriculum and Bloom's Revised Taxonomy to measure students' understanding of the Solar System topic. The Student Attention Questionnaire comprised 15 Likert-scale items adapted from the Cognitive Engagement Theory, covering four dimensions: concentration, participation, responsiveness, and task persistence. The Classroom Observation Sheet was developed based on the Differentiated Instruction Framework to monitor instructional implementation, student participation, and classroom engagement during the intervention. Prior to implementation, all instruments were evaluated by three experts to establish content validity using Aiken's V and tested for reliability using KR-20 for the achievement test and Cronbach's alpha for the questionnaire. The results indicated that all instruments met acceptable validity and reliability standards and were appropriate for use in this study. A summary of the research instruments is presented in Table 4.

Table 4. Research instruments

Instrument	Source/Adapted From	Construct Measured	Indicators	Items	Validity (Aiken's V)	Reliability
Science Achievement Test	Merdeka Curriculum (Grade VI IPAS); Bloom's Revised Taxonomy	Science Achievement	Conceptual understanding, application, and problem-solving	20 (MCQ)	0.91	KR-20 = 0.82
Student Attention Questionnaire	Cognitive Engagement Theory	Student Attention	Concentration, participation, responsiveness, task persistence	15 (Likert)	0.89	Cronbach's α = 0.87
Classroom Observation Sheet	Differentiated Instruction Framework	Implementation Fidelity	Instructional implementation, student participation, classroom engagement	Checklist	0.90	Inter-rater agreement

Table 4 shows that all research instruments demonstrated satisfactory psychometric quality. The Science Achievement Test was administered as both the pretest and posttest to measure changes in students' learning outcomes, whereas the Student Attention Questionnaire was administered after the intervention to evaluate students' attention during learning. The Classroom Observation Sheet was used to monitor the fidelity of the implementation of Wordwall-based differentiated instruction and to support the interpretation of the quantitative findings.

Data Analysis Techniques

Data were analyzed using descriptive and inferential statistical techniques. Descriptive statistics, including the mean, standard deviation, minimum score, maximum score, and gain score, were used to summarize students' science learning outcomes before and after the instructional intervention. Prior to hypothesis testing, the assumptions of normality and homogeneity of variance were examined using the Shapiro–Wilk and Levene's tests, respectively. The research hypothesis was tested using an independent-samples *t*-test to compare the posttest scores of the experimental and control groups. Furthermore, Cohen's *d* was calculated to estimate the practical significance of the instructional intervention. Statistical significance was determined at the 0.05 level.

Conceptual Framework of the Study

Conceptual framework of this study proposes that Wordwall-based differentiated instruction enhances students' learning by providing differentiated activities that accommodate learners' readiness, interests, and learning needs (Lehtinen et al., 2025). Drawing on Constructivist Learning Theory and Cognitive Engagement Theory, this instructional approach is expected to increase student attention, leading to improved science achievement. These relationships

provide the theoretical basis for examining the effectiveness of the instructional intervention.

Conceptual framework of this study proposes that Wordwall-based differentiated instruction enhances student attention and science achievement based on Constructivist Learning Theory and Cognitive Engagement Theory (Toikka et al., 2024).

Table 5 indicates that students in both groups demonstrated improved science learning outcomes following the instructional process. The pretest means of the experimental (61.47) and control (60.88) groups were relatively similar. After the intervention, the experimental group achieved a higher mean posttest score (84.26) than the control group (72.35). Furthermore, students who received Wordwall-assisted differentiated instruction showed greater improvement from pretest to posttest than those who learned through the Drill and Practice method.

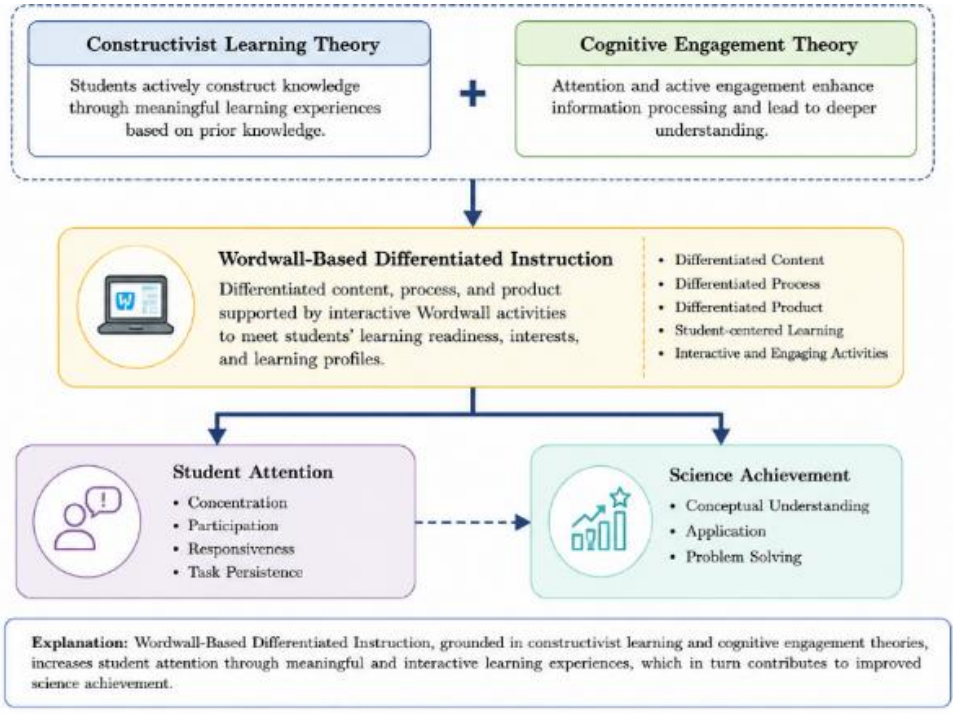

Figure 2. Conceptual framework of the study

Table 5. Descriptive statistics of students' science learning outcomes

Group	N	Mean Pretest	Mean Posttest	SD (Posttest)	Gain Score
Experimental (Wordwall-assisted Differentiated Instruction)	16	61.47	84.26	6.21	22.79
Control (Drill and Practice)	16	60.88	72.35	7.04	11.47

Preliminary Assumption Tests

Prior to hypothesis testing, normality and homogeneity tests were conducted to verify whether the assumptions required for the independent-samples *t*-test were satisfied.

Table 6. Normality test results

Group	Sig. Value	α	Decision
Experimental Pretest	0.200	0.05	Normal
Experimental Posttest	0.200	0.05	Normal
Control Pretest	0.200	0.05	Normal
Control Posttest			

As presented in Table 6, all significance values exceeded the significance level of 0.05. Therefore, the pretest and posttest scores of both groups were normally distributed. Consequently, the assumption of normality required for the independent-samples t-test was satisfied.

Table 7. Homogeneity test results

Variable	Levene Statistic	Sig.	Decision
Science Learning Outcomes	0.647	> 0.05	Homogeneous

Table 7 shows that the significance value of Levene's test was greater than 0.05, indicating that the variances of the experimental and control groups were homogeneous. Consequently, the independent-samples *t*-test was considered appropriate for testing the research hypothesis.

Hypothesis Testing

The research hypothesis examined whether there was a significant difference in posttest science learning outcomes between students who received Wordwall-assisted differentiated instruction and those who received the Drill and Practice method. The hypothesis was tested using an independent-samples t-test.

H_0: There is no significant difference in posttest science learning outcomes between students taught using Wordwall-assisted differentiated instruction and those taught using the Drill and Practice method.

H_1: There is a significant difference in posttest science learning outcomes between students taught using Wordwall-assisted differentiated instruction and those taught using the Drill and Practice method.

The independent-samples *t*-test revealed a *t*-value of 4.215, which exceeded the critical value of 1.977. The obtained significance value (p = 0.000) was lower than the established significance level of 0.05. Therefore, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was accepted. These findings indicate that students who received Wordwall-assisted differentiated instruction achieved significantly higher posttest science learning outcomes than those who learned through the Drill and Practice method.

Table 8. Independent-samples t-test results

Group Comparison	Mean Difference	T	$t_{critical}$	Sig. (2-tailed)	Decision
Experimental vs. Control	11.91	4.215	1.977	0.000	Reject H_0

Practical Significance of the Intervention

To evaluate the magnitude of the instructional intervention, Cohen's *d* effect size was calculated. The results are presented in Table 9.

Table 9. Effect size analysis

Comparison	Cohen's d	Interpretation
Experimental vs. Control	0.92	Large Effect

The calculated Cohen's *d* value of 0.92 indicates a large effect size according to Cohen's interpretation criteria. This finding demonstrates that Wordwall-assisted differentiated instruction not only produced statistically significant differences but also had substantial practical significance in improving students' science learning outcomes.

Discussion

The findings of this study demonstrate that Wordwall-assisted differentiated instruction effectively improves elementary students' science learning outcomes. Descriptive analysis showed that although both the experimental and control groups experienced improvement after the instructional process, students who learned through Wordwall-assisted differentiated instruction achieved higher posttest scores and greater learning improvement than those who received the conventional Drill and Practice method. These findings indicate that combining differentiated instruction with interactive digital media creates learning experiences that better accommodate students' diverse readiness levels and learning needs, thereby facilitating more meaningful conceptual understanding. The present findings are consistent with those reported by Saputri et al. (2024), who found that Wordwall-assisted learning significantly improved elementary students' scientific literacy by promoting active participation, collaborative learning, and higher engagement compared with conventional instruction. Their quasi-experimental study concluded that integrating Wordwall into classroom instruction created a more interactive learning environment that enhanced students' science achievement. Likewise, Pratiwi et al. (2025) demonstrated that differentiated learning significantly improved elementary students' science learning outcomes because instructional activities were adjusted to students' learning characteristics and readiness levels. These converging findings strengthen the present study by confirming that the integration of differentiated instruction with Wordwall provides a more effective instructional strategy for improving science learning outcomes than conventional teacher-centered instruction.

The hypothesis testing further reinforces this conclusion. The independent-samples *t*-test revealed a statistically significant difference in posttest science learning outcomes between the experimental and control groups, leading to the rejection of the null hypothesis and acceptance of the alternative hypothesis. This finding indicates that the higher learning outcomes achieved by the experimental group were attributable to the implementation of Wordwall-assisted differentiated instruction rather than random variation. Similar evidence was reported by Hidayah et al. (2025), who demonstrated that Problem-Based Learning assisted by Wordwall within a differentiated learning environment produced significantly higher learning outcomes than conventional instruction in elementary schools. Their study also employed a quasi-experimental design and independent-samples *t*-test, confirming that the integration of Wordwall into differentiated learning effectively enhances students' academic achievement. Furthermore, Yustin et al. (2025) emphasized that Wordwall-supported differentiated learning enables

teachers to accommodate diverse student characteristics while creating more engaging and inclusive classroom environments, thereby increasing students' participation and learning effectiveness. Therefore, the present findings not only confirm previous empirical evidence but also strengthen the growing body of research demonstrating that Wordwall-assisted differentiated instruction is an effective pedagogical approach for improving elementary students' science learning outcomes.

Beyond statistical significance, the large effect size obtained in this study indicates that the instructional intervention also has substantial practical significance. A Cohen's *d* value of 0.92 suggests that the observed improvement is educationally meaningful and reflects a strong instructional impact in classroom practice. This finding implies that integrating Wordwall into differentiated instruction not only produces statistically significant gains but also generates meaningful improvements that can be implemented in real classroom settings. Similar conclusions were reported by Sari et al. (2024), who found that differentiated instructional materials significantly enhanced elementary students' science process skills by accommodating individual learning differences and promoting active engagement. In addition, the findings of Rifayanti et al. (2024) confirmed that differentiated instruction effectively improves science learning outcomes when learning activities are designed according to students' readiness and learning profiles. Collectively, these findings reinforce the conclusion that integrating differentiated instruction with Wordwall not only confirms previous evidence regarding the effectiveness of digital learning media but also extends existing empirical evidence by demonstrating that such integration produces both statistically significant and practically meaningful improvements in elementary science learning (Towers et al., 2023). Consequently, this instructional approach offers valuable implications for implementing student-centered learning within the framework of the curriculum while supporting the achievement of Sustainable Development Goal 4 through the provision of inclusive, engaging, and high-quality science education (López-fernández et al., 2023).

Conclusion

Evidence obtained from this study demonstrates that Wordwall-assisted differentiated instruction is a more effective instructional approach than the conventional Drill and Practice method for improving elementary students' science learning outcomes. Students who participated in Wordwall-assisted differentiated instruction achieved higher posttest performance and greater learning improvement than those receiving conventional instruction. Statistical analysis confirmed a significant difference between the experimental and control groups, while the large effect size indicates that the instructional intervention produced not only statistical significance but also substantial educational value in enhancing science achievement. Integration of Wordwall with differentiated instruction contributes to the growing body of research on technology-enhanced learning by providing empirical evidence that interactive digital media, when combined with differentiated teaching strategies, creates a more adaptive, engaging, and learner-centered instructional environment. Accommodation of students' diverse readiness levels and learning needs through this integrated approach enables teachers to deliver equitable learning opportunities while maintaining common instructional objectives. Findings from the present study therefore extend existing empirical evidence by demonstrating that the combination of Wordwall and differentiated instruction represents an effective pedagogical strategy for improving science learning outcomes in elementary education. Practical implications of this study suggest that Wordwall-assisted differentiated instruction can be adopted as an evidence-based instructional alternative for elementary school teachers seeking to create engaging, inclusive, and student-centered science learning environments. Integration of interactive digital media into differentiated classroom practices also offers opportunities to enhance learning quality while responding to students' diverse characteristics and learning profiles. Several limitations should be acknowledged when interpreting the findings. Data were collected from a relatively small sample within a single elementary school, which may limit the generalizability of the results to broader educational settings. Future research is therefore encouraged to involve larger and more diverse samples, investigate different educational contexts and subject areas, employ longitudinal or mixed-methods research designs, and examine additional learning outcomes such as higher-order thinking skills, scientific reasoning, learning motivation, student engagement, and learning retention. Broader investigations will contribute to a more comprehensive understanding of the long-term effectiveness and educational impact of Wordwall-assisted differentiated instruction across elementary education.

Acknowledgements

The authors would like to express their sincere gratitude to the principal, teachers, and students of the participating elementary school for their cooperation and active participation throughout this study. Appreciation is also

extended to the academic supervisors and expert validators for their valuable guidance, constructive feedback, and professional insights during the research process. Their contributions greatly supported the successful completion of this study. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Contributions

Conceptualization was carried out by M.D.C.R. and J.S. Methodology design was developed collaboratively by M.D.C.R. and J.S. Software development was handled by M.D.C.R. Validation was performed by M.D.C.R., J.S., and A.B. Formal analysis was conducted by M.D.C.R. Investigation and data collection were carried out by M.D.C.R. Resources were managed by M.D.C.R. Data curation was performed by M.D.C.R. The original draft of the manuscript was prepared by M.D.C.R. Writing—review and editing were conducted by J.S. and A.B. Visualization was prepared by M.D.C.R. Supervision was provided by J.S. and A.B. Project administration was managed by M.D.C.R. Funding acquisition was the responsibility of J.S. All authors have read and agreed to the published version of the manuscript.

Funding

The authors certify that they have no known financial or personal relationships that could have influenced the work reported in this paper. This research received no external funding. The authors are solely responsible for the design, implementation, analysis, and interpretation of the study. The APC was not funded by any external organization or funding agency.

Conflicts of Interest

The authors declare that they have no known financial or personal relationships that could have influenced the findings reported in this manuscript. The authors also confirm that there are no conflicts of interest associated with this research.

References

Agustina, L., Fitriani, S., & Fatayan, A. (2025). Empowering Gen Z Learning: Wordwall-Based Educational Game Development in Differentiated Instruction for Elementary Students. *Mimbar Sekolah Dasar*, *12*(2), 241–268. https://doi.org/10.53400/mimbar-sd.v12i2.86746

Anwar, Y. A. S., Idrus, S. W. A., & Junaidi, E. (2024). Implementation of Integrated Problem-Based Learning and Storytelling Technique on Learning Outcomes and Attitudes Towards Chemistry. *Jurnal Pendidikan Progresif*, *14*(2), 1059–1070. https://doi.org/10.23960/jpp.v14.i2.202477

Asipi, L. S., Rosalina, U., & Nopiyadi, D. (2022). The Analysis of Reading Habits Using Miles and Huberman Interactive Model to Empower Students' Literacy at IPB Cirebon. *International Journal of Education and Humanities*, *2*(3), 117–125. https://doi.org/10.58557/ijeh.v2i3.98

Asnawi, A., Sahudra, T. M., Ramadhani, D., Kenedi, A. K., Aosi, G., Wardhana, M. R., & Khalil, N. A. (2023). Development of Digital Diagnostic Test Instruments for Differentiated Learning Process in Elementary Schools. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 460–466. https://doi.org/10.29303/jppipa.v9iSpecialIssue.6125

Aulia, D., Azmi, C., & Fitria, Y. (2023). Implementation of Webbed Type Integrated Learning to Improve Student Learning Activities. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 7775–7783. https://doi.org/10.29303/jppipa.v9i10.3959

Creswell, J. W., & Creswell, J. D. (2023). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (6th ed.). SAGE Publications.

Darmawan, E., Ramadani, S. D., Normawati, A., Krisma, D. A., Admawati, H., & Agustyaningrum, N. (2025). Enhancing Preservice Teachers' Metacognition and Critical Thinking Through the ERIC Learning Model. *Indonesian Journal of Educational Development (IJED)*, *6*(3), Pages: https://doi.org/10.59672/ijed.v6i3.5026

Dayanti, S., Alpusari, M., & Witri, G. (2023). Development of Interactive Learning Media on Human Respiratory System Learning Material at Grade V Elementary School. *Primary: Jurnal Pendidikan Guru Sekolah Dasar*, *12*(1), 134–146. https://doi.org/10.33578/jpfkip.v12i1.8974

Dewi, S. M., Nur, D. S. Y., Sa'diah, T. L., & Sa'adah, H. M. R. H. (2024). Wordwall Media with a Gameshow-Quiz Type to Increase Students' Interest in IPAS Learning at Elementary School. *MIMBAR PGSD Undiksha*, *12*(2), 312–320. https://doi.org/10.23887/jjpgsd.v12i2.78681

Fabrigar, L. R., Vaughan-Johnston, T. I., & Wegener, D. T. (2024). *Handbook of Research Methods in Social and Personality Psychology* (pp. 160–192). Cambridge University Press. https://doi.org/10.1017/9781009170123.009

Flegr, S., Kuhn, J., & Scheiter, K. (2023). When the Whole Is Greater Than the Sum of Its Parts: Combining Real and Virtual Experiments in Science Education. *Computers & Education*, *197*, 104745. https://doi.org/10.1080/21532974.2023.2244597

Folwell, E. J., Brennan, J. D., & Brennan, J. D. (2025). Assessment & Evaluation in Higher Education Assessment by Engagement: Building Confidence and Autonomy in the First Year. *Assessment & Evaluation in Higher Education*, *50*(6), 819–832. https://doi.org/10.1080/02602938.2025.2483268

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2023). *How to Design and Evaluate Research in Education*. McGraw Hill LLC.

Getenet, S., & Tualaulelei, E. (2023). Using Interactive Technologies to Enhance Student Engagement in Higher Education Online Learning. *Journal of Digital Learning in Teacher Education*, *39*(4), 220–234. https://doi.org/10.1080/21532974.2023.2244597

Halim, A., Iskandar, I., Ansari, A., & Halim, N. M. (2024). A Study on How the Merdeka Curriculum Promotes Multilingualism in Indonesian ELT Classrooms. *XLinguae*, *17*(2), 107–121. https://doi.org/10.18355/XL.2024.17.02.07

Hamidah, F., Setiawan, F., & Mirnawati, L. B. (2023). Strenghthening Digital Literacy of Elementary School Students Through Utilization of Wordwall as Game-Based Learning Interactive Media. *Jurnal Ilmiah Sekolah Dasar*, *7*(2), 215–223. https://doi.org/10.23887/jisd.v7i2.55807

Hidayah, H., Ridhotul, S., Aeni, A., & Kurotul, K. (2025). The Effectiveness of Problem-Based Learning Assisted by Wordwall in Terms of Differentiated Instruction and Learning Achievement of Second-Grade Elementary School Students. *Pedagogik Journal of Islamic Elementary School*, *9*(1), 251–268. https://doi.org/10.24256/pijies.v9i1.10035

Hidayati, R., & Eriyanti, F. (2023). Differentiated Learning Technology on Science Education to Students Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *9*((SpecialIssue)), 1017–1022. https://doi.org/10.29303/jppipa.v9iSpecialIssue.6479

Istiqomah, L., & Wibowo, S. E. (2024). Effective Learning of Pancasila Education Through Technology-Based Interactive Media for Elementary School Students. *Jurnal Pendidikan Progresif*, *14*(3), 1990–2004. https://doi.org/10.23960/jpp.v14.i3.2024135

Julianto, F., Hidayati, F., Rahmawati, J. F., Cahyaningsih, R., & & Surrahman, I. (2023). Training Students' Critical Thinking Skills Through Inquiry Models to Minimize Science Misconceptions. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 1011–1015. https://doi.org/10.29303/jppipa.v9i11.3757

Karimian, Z., & Chahartangi, F. (2024). Development and Validation of a Questionnaire to Measure Educational Agility: A Psychometric Assessment Using Exploratory Factor Analysis. *BMC Medical Education*. https://doi.org/10.1186/s12909-024-06307-z

Kharisma, A. I., Ati, A. F. S., Elisah, A. D. M., Fillah, I. Z., & Widiyanti, W. (2023). The Effectiveness of Hybrid Project-Based Learning Model in Improving Primary Teacher Education Students' Critical Thinking and Creative Thinking. *JPFKIP*, *12*(5), 1203–1215. https://doi.org/10.33578/jpfkip.v12i5.9967

LeChasseur, L. (2024). Validity of a Self-Report Measure of Student Learning in Active Learning Statics Courses. *The Journal of Experimental Education*, *53*(4), 751–771. https://doi.org/10.1177/03064190241253509

Lehtinen, E., Hakkarainen, K., & Palonen, T. (2025). Cognitive Engagement and Knowledge Construction in Technology-Enhanced Learning. *Learning and Instruction*, *92*, 101897. https://doi.org/10.1016/j.learninstruc.2025.101897

Lestari, T. (2023). Exploration of Technology-Assisted Summative Assessment Instruments in Differentiation Learning. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8925–8933. https://doi.org/10.29303/jppipa.v9i10.4342

López-fernández, D., Gordillo, A., Pérez, J., & Tovar, E. (2023). Learning and Motivational Impact of Game-Based Learning: Comparing Face-To- Face and Online Formats on Computer Science Education. *TE*, *66*(4), 360–368. https://doi.org/10.1109/TE.2023.3241099

Meutstege, K., & Geel, M. V. (2023). Education Sciences Evidence-Based Design of a Teacher Professional Development Program for Differentiated Instruction : A Whole-Task Approach. *Education Sciences*, *13*(10), 985. https://doi.org/10.3390/educsci13100985

Napitupulu, N. M., Panjaitan, M., & Sitio, H. (2023). Pengaruh Model Pembelajaran Contextual Teaching Learning (CTL) Terhadap Hasil Belajar Siswa pada Mata Pelajaran IPA di Kelas V UPTD SD Negeri 122353 Pematangsiantar. *Journal on Education*, *5*(4), 14550–14562. https://doi.org/10.31004/joe.v5i4.2509

Nasution, K., & Suyanto, S. (2023). A Comparison of Students' Mathematical Communication Ability Taught by Contextual Teaching and Learning Versus Problem Based Learning. *Jurnal Pendidikan Progresif*, *13*(2), 255–267. https://doi.org/10.23960/jpp.v13.i2.202309

Nur, M., Sasmita, R. A., Rompeggading, A. B., & Irfandi, R. (2023). The Effect of Learning Everyone Is a Teacher Here in Combined Differentiate Learning on Science Literation Ability and Learning Motivation. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4652–4657. https://doi.org/10.29303/jppipa.v9i6.3948

Pratiwi, P., Kusuma, E., Tyas, T., & Nilam, D. (2025). The Effectiveness of Implementing Learning Style Differentiation on Science Learning Interests and Outcomes in Elementary Schools. *Jurnal Penelitian Pendidikan IPA*, *11*(4), 243–253. https://doi.org/10.29303/jppipa.v11i4.10670

Reichardt, C. S., Storage, D., & Abraham, D. (2023). Quasi-Experimental Research. In A. L. Nichols & J. Edlund (Eds.). In *The Cambridge Handbook of Research Methods and Statistics for the Social and Behavioral*

Sciences (pp. 292–313). Cambridge University Press. https://doi.org/10.1017/9781009010054.015

Ridwan, I. R., Susilawati, U. N. D., Hanif, M., Larasati, N., Gandoria, A. P., Sadiyah, M., S., Adsabila, I., & Rahmawati, P. (2023). The Effect of Wordwall Educational Game on Students' Learning Interest in the High-Grade Mathematics Learning Subjects in Elementary School. *Primary: Jurnal Pendidikan Guru Sekolah Dasar*, *12*(4), 1163–1173. https://doi.org/10.33578/jpfkip.v12i4.9123

Rifayanti, Z. E. T., Mustaji, M., Mariana, N., & Suryanti, S. (2024). Enhancing Critical Thinking and Problem-Solving Skills in Upper Elementary Students Through Game-Based Learning. *Perspectives of Science and Education*, *70*(4), 396–420. https://doi.org/10.32744/pse.2024.4.25

Rönn-liljenfeldt, M., Sundqvist, C., Ström, K., Korhonen, J., & Rönn-liljenfeldt, M. (2024). Students' Perceptions of Co-Teaching in the General Classroom. *European Journal of Special Needs Education*, *39*(2), 311–326. https://doi.org/10.1080/08856257.2023.2215008

Saputri, S., Luthfi, A., & Sukmawati, W. (2024). The Influence of the Team Games Tournament (TGT) Learning Model Assisted by Wordwall on the Scientific Literacy of Class V Elementary School Students. *Jurnal Penelitian Pendidikan IPA*, *10*(7), 3787–3798. https://doi.org/10.29303/jppipa.v10i7.7992

Sari, S., Karunika, S. M. N., Tegeh, I. M., & Made, I. (2024). Practical Instructions with Content Differentiation to Improve Elementary School Students' Science Process Skills. *Jurnal Pedagogi dan Pembelajaran*, *7*(1), 183–193. https://doi.org/10.23887/jp2.v7i1.74540

Siami, F., Sumarni, W., Sudarmin, S., & Harjono, A. (2023). Development of Integrated LKPD Ethnoscience Batik Semarang to Improve Students' Chemical Literacy. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 7784–7792. https://doi.org/10.29303/jppipa.v9i10.3604

Sunarti, S., Anggraini, D. S., & Jana, P. (2023). The Effectiveness of Pop-Up Book Media in Learning Reading Skills of Grade 2 Elementary School. *Cakrawala Pendidikan*, *42*(2), 493–506. https://doi.org/10.21831/cp.v42i2.50381

Tajik, O., Noor, S., & Golzar, J. (2024). Investigating Differentiated Instruction and the Contributing Factors to Cater EFL Students' Needs at the Collegial Level. *Asian-Pacific Journal of Second and Foreign Language Education*. https://doi.org/10.1186/s40862-024-00299-5

Toikka, S., Eronen, L., Atjonen, P., & Havu-nuutinen, S. (2024). Combined Conceptualisations of Metacognitive Knowledge to Understand Students' Mathematical. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2357901

Towers, E., Rushton, E. A. C., Gibbons, S., Steadman, S., Brock, R., Cao, Y., Finesilver, C., Jones, J., Manning, A., Richardson, C., & Marshall, B. (2023). The "Problem" of Teacher Quality: Exploring Challenges and Opportunities in Developing Teacher Quality During the Covid-19 Global Pandemic in England. *Educational Review*, *0*(0), 1–17. https://doi.org/10.1080/00131911.2023.2184771

Tran, T. T., & Nagirikandalage, P. (2025). Insights into Enhancing Student Engagement: A Practical Application of Blended Learning. *The International Journal of Management Education*, *23*(2), 101167. https://doi.org/10.1016/j.ijme.2025.101167

Witraguna, K. Y., Ayu, G., Setiawati, D., Nyoman, N., Wahyuni, T., Manik, I. K., Jaya, A., Kadek, N., & Anggreni, A. (2024). Learning in the Merdeka Curriculum: Elementary School Teachers' Understanding of Differentiated Learning. *International Journal of Elementary Education*, *8*(1), 47–56. https://doi.org/10.23887/ijee.v8i1.69779

Yustin, Y., Hastuti, Y. N., Anif, A., Sofyan, S., Desstya, D., Anatri, A., & Minsih, M. (2025). Innovation in Differentiated Learning Assisted by Digital Media Wordwall in Accommodating Elementary School Learning Needs. *Jurnal Elementaria Edukasia*, *8*(1), 113–124. https://doi.org/10.31949/jee.v8i1.12843