

Effect of Wordwall-Assisted Differentiated Instruction on Sixth-Grade Students' Science Achievement: A Quasi-Experimental Study

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ARTICLE INFO	ABSTRACT
Article history: Submitted: September 17, 2026 Final Revised: Sept. 22, 2026 Accepted: September 29, 2026 Published: September 30, 2026 Keywords: Differentiated Instruction; Elementary Science; Wordwall; Wordwall-Based Learning	Purpose: This study examined the effectiveness of Wordwall-assisted differentiated instruction in improving sixth-grade students' science learning outcomes. Methods: 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 to the control group. Data were collected using a 20-item researcher-developed science learning outcomes test based on Grade VI IPAS learning outcomes and Bloom's Revised Taxonomy. The test was administered before and after the intervention. Descriptive statistics were used to summarize students' performance, while normality and homogeneity tests were conducted as prerequisites for hypothesis testing. An independent-samples <i>t</i>-test was used to compare posttest scores between groups, and Cohen's <i>d</i> was calculated to determine the magnitude of the intervention effect. Findings: The results showed a statistically significant difference in posttest science learning outcomes between the experimental and control groups ($p < .05$). Students who received Wordwall-assisted differentiated instruction achieved higher posttest scores than those who received the Drill and Practice method. The intervention produced a large effect size (Cohen's $d = 0.92$), indicating a substantial difference between the groups. Implications: The findings indicate that integrating Wordwall with differentiated instruction may provide an interactive approach to supporting science learning outcomes among elementary students. Originality: This study contributes empirical evidence on the integration of an interactive digital learning medium with differentiated instruction to address diverse learning needs in elementary science education



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INTRODUCTION

Improving the quality of human resources and preparing students to develop competencies required in the 21st century are important priorities in contemporary education. 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). The curriculum also encourages differentiated instruction and the use of technology to accommodate students' diverse learning needs (Asnawi et al., 2023). At the elementary level, Natural and Social Sciences (IPAS) is designed to develop students' conceptual understanding through contextual, inquiry-based, and interactive learning experiences. Accordingly, instructional approaches that accommodate learner diversity while providing meaningful learning activities are needed to improve students' science learning outcomes (Aulia et al., 2023).

Despite these curricular expectations, science learning at the elementary level remains challenging. Abstract topics, including the solar system, can be difficult for students to understand when instruction relies primarily on verbal explanations and conventional exercises (Lestari, 2023). Previous studies have reported low science achievement, limited classroom participation, and difficulties in developing conceptual understanding among elementary students (Asipi et al., 2022). Similar challenges have been identified in Indonesian science classrooms, including conceptual misconceptions and limited opportunities for active interaction during learning (Julianto et al., 2023). Preliminary observations in Grade VI classrooms in Bogorejo District, Blora Regency, indicated that only 43% of students achieved the Minimum Mastery Criterion (KKM) in the solar system topic, whereas 57% did not reach the expected competency level. Classroom observations further indicated that more than half of the students were relatively passive during science lessons. Teacher interviews also indicated that instruction remained predominantly teacher-centered and made limited use of interactive digital learning media (Al-Shehri, 2020).

These conditions indicate the need for instructional approaches that accommodate learner differences while providing opportunities for active and meaningful science learning (Getenet & Tualaulelei, 2023).

One approach that can address learner diversity is differentiated instruction. Differentiated instruction enables teachers to adapt learning content, processes, and products according to students' readiness, interests, and learning profiles (Witraguna et al., 2024). Rather than providing identical learning experiences for all students, differentiated instruction allows teachers to vary instructional activities and forms of support according to students' learning needs. Previous research has indicated that differentiated instruction can promote more responsive learning environments and provide students with learning experiences that are better aligned with their individual characteristics (Napitupulu et al., 2023). Within the context of the Merdeka Curriculum, this approach is relevant because learning is expected to respond to differences in students' abilities, readiness, and learning needs (Achmad et al., 2024).

The effectiveness of differentiated instruction can potentially be strengthened through interactive digital learning media. Wordwall is a digital learning platform that provides various interactive activities, including quizzes, matching exercises, word games, and other game-based learning formats. These features provide opportunities for practice and feedback while presenting learning activities in interactive formats. Previous studies have reported positive associations between Wordwall-based learning and students' motivation, participation, and academic achievement (Agustina et al., 2025). Interactive digital media can also increase opportunities for classroom interaction and provide immediate feedback during learning (Lestari, 2023). In science education, game-based digital learning may support conceptual understanding by allowing students to interact repeatedly with learning content in an engaging and structured environment (Siami et al., 2023).

The integration of differentiated instruction and Wordwall can be understood through complementary instructional mechanisms. Differentiated instruction addresses learner variability by adapting learning activities to students' readiness and learning needs, whereas Wordwall provides an interactive digital environment in which these adapted activities can be practiced through varied tasks and immediate feedback. The combination of these approaches may therefore provide learning experiences that are responsive to individual differences while maintaining active interaction with science concepts. In the present study, Wordwall is positioned not merely as a replacement for conventional exercises but as an interactive medium integrated into differentiated instructional activities. This integration provides a basis for examining its potential contribution to students' science learning outcomes compared with the Drill and Practice method.

The theoretical foundation of this study is primarily derived from Tomlinson's Differentiated Instruction Theory and Constructivist Learning Theory. Tomlinson's framework emphasizes adapting content, learning processes, and learning products according to students' readiness, interests, and learning profiles. Constructivist Learning Theory explains that meaningful learning occurs when students actively construct knowledge through interaction with learning experiences rather than simply receiving information from teachers (Hidayati & Eriyanti, 2023). Wordwall can support this process by providing interactive tasks through which students respond to questions, receive feedback, and repeatedly engage with science concepts. Therefore, the integration of differentiated instruction and Wordwall provides a theoretically grounded approach for creating learning experiences that accommodate learner differences while encouraging active construction of scientific knowledge (Nur et al., 2023).

Previous studies have examined differentiated instruction and Wordwall-assisted learning as separate approaches, but the empirical literature provides less evidence concerning their integrated application in elementary IPAS learning within the context of the Merdeka Curriculum. Existing research has generally focused either on differentiated instruction as a pedagogical approach or on Wordwall as an interactive digital learning medium. Comparatively fewer studies have examined how these two components can be deliberately integrated into a single instructional framework to address learner diversity and improve elementary science learning outcomes. The present study therefore addresses a specific empirical gap concerning the implementation of Wordwall-assisted differentiated instruction in Grade VI IPAS learning, particularly in the solar system topic (Ringo & S, 2025).

The present study aims to examine the effect of Wordwall-assisted differentiated instruction on sixth-grade students' science learning outcomes. A quasi-experimental pretest–posttest control group design was employed to compare students who received Wordwall-assisted differentiated instruction with those who received the Drill and Practice method. The study focuses on determining whether the implementation of Wordwall-assisted differentiated instruction results in higher posttest science learning outcomes than the Drill and Practice method. Based on the theoretical framework and empirical evidence from previous studies, the study hypothesizes that students who receive Wordwall-assisted differentiated instruction will achieve higher posttest science learning outcomes than students who receive the Drill and Practice method.

This study contributes to the literature by examining the integration of an interactive digital learning platform with differentiated instruction as a unified instructional approach. It provides empirical evidence from Grade VI IPAS learning within the implementation of the Merdeka Curriculum, with a particular focus on the solar system topic. By comparing the science learning outcomes of students who receive Wordwall-assisted differentiated

instruction with those who receive the Drill and Practice method, the study extends empirical evidence on the application of technology-supported differentiated instruction in elementary science education.

METHOD

Research Design

This study employed a quasi-experimental pretest–posttest control group design to examine the effect of Wordwall-assisted differentiated instruction on students' science learning outcomes. The design involved an experimental group that received Wordwall-assisted differentiated instruction and a control group that received the conventional Drill and Practice method. Both groups completed the same science achievement test before and after the intervention. The pretest was administered to establish students' baseline achievement, while the posttest was used to examine differences in science learning outcomes following the instructional intervention (Creswell & Creswell, 2023).

The quasi-experimental design was selected because random assignment of individual students was not feasible within the existing classroom structure. The design therefore enabled a comparison between two intact classroom groups under authentic elementary school learning conditions (Sunarti et al., 2023).

Variables of the Study

The study involved one independent variable and one dependent variable. The independent variable was Wordwall-assisted differentiated instruction, which represented the instructional treatment provided to the experimental group. The dependent variable was students' science learning outcomes on the Solar System topic, measured through the science achievement test (Meutstege & Geel, 2023).

Table 1. Variables of the Study

Variable Type	Variable	Role in the Study
Independent variable	Wordwall-assisted differentiated instruction	Instructional treatment
Dependent variable	Science learning outcomes	Learning achievement measured through pretest and posttest

Thus, the study focused exclusively on the effect of Wordwall-assisted differentiated instruction on science learning outcomes. Student attention was not treated as a research variable or outcome in the present study.

Population and Sample

The study involved 32 sixth-grade students from two elementary schools in the Madukoro Cluster, Central Java, Indonesia. The participants consisted of 16 students in the experimental group and 16 students in the control group. The experimental group received Wordwall-assisted differentiated instruction, whereas the control group received the conventional Drill and Practice method. The schools were selected using purposive sampling based on predefined criteria, including implementation of the Merdeka Curriculum and suitability for implementing the planned instructional intervention. The use of intact classroom groups was necessary because individual random assignment was not feasible within the participating schools.

Before the intervention, all students completed a science achievement pretest. The pretest scores were used to describe the initial achievement levels of both groups and to assess baseline comparability before the intervention. Because the study involved intact classrooms from two schools, the findings are interpreted within the context of the participating classes and should not be generalized beyond comparable educational settings without further evidence (Hollander et al., 2025).

The sample consisted of 16 students per group. No a priori statistical power analysis was conducted because the study was conducted within the available intact classroom populations. Therefore, the findings should be interpreted as evidence from a small-scale classroom-based quasi-experimental study rather than as broadly generalizable population estimates (Aguhayon et al., 2023).

Research Procedure

The research procedure consisted of three phases: preparation, implementation, and post-intervention assessment. During the preparation phase, classroom observations were conducted to identify students' learning difficulties and existing instructional practices in Grade VI IPAS, particularly on the Solar System topic. The science achievement test and lesson plans were subsequently reviewed by experts to establish content validity and appropriateness for Grade VI students. The instructional materials and Wordwall activities were prepared according to the learning objectives and differentiated learning activities (Rizki & Suprpto, 2024).

During the implementation phase, the intervention was conducted over four instructional sessions, with each session lasting approximately 70 minutes. The experimental group received Wordwall-assisted differentiated instruction, while the control group received the Drill and Practice method.

In the experimental group, differentiated instruction was implemented by adapting learning content, learning processes, and student tasks according to students' readiness levels. The initial readiness information was obtained from the pretest and classroom observations. Students were provided with learning activities appropriate to their identified readiness levels. Wordwall was integrated into these activities through interactive quizzes, matching

activities, and game-based exercises. The activities provided students with opportunities to practice science concepts and receive immediate feedback.

The control group received instruction through the Drill and Practice method. Learning activities focused on teacher explanations, conventional exercises, and repeated practice of the relevant Solar System concepts without the Wordwall-assisted differentiated instructional framework.

During the intervention, classroom observations were used to monitor whether the planned instructional activities were implemented as intended. The observation focused on the implementation of differentiated learning activities, the use of Wordwall in the experimental group, adherence to the planned instructional sequence, and student participation during the learning process.

During the post-intervention phase, both groups completed the same science achievement posttest. The pretest and posttest data were subsequently analyzed to determine differences in science learning outcomes between the two instructional conditions.

Table 2. Implementation of Wordwall-Assisted Differentiated Instruction

Session	Learning Focus	Differentiated Instruction	Wordwall Activity	Expected Outcome
1	Introduction to the Solar System	Diagnostic assessment and grouping based on readiness	Interactive quiz	Identification of students' initial understanding
2	Planet Characteristics	Content adapted to students' readiness levels	Matching Pairs and Quiz	Improved understanding of planetary characteristics
3	Solar System Problem Solving	Differentiated learning processes through collaborative activities	Gameshow Quiz and Random Wheel	Improved understanding through interactive practice
4	Review, Reflection, and Evaluation	Differentiated learning products through formative assessment	Interactive Quiz	Consolidation and evaluation of science learning

The implementation sequence was designed to connect differentiated learning with interactive Wordwall activities. The differentiated component addressed variation in students' readiness, while Wordwall provided interactive opportunities for practice and feedback.

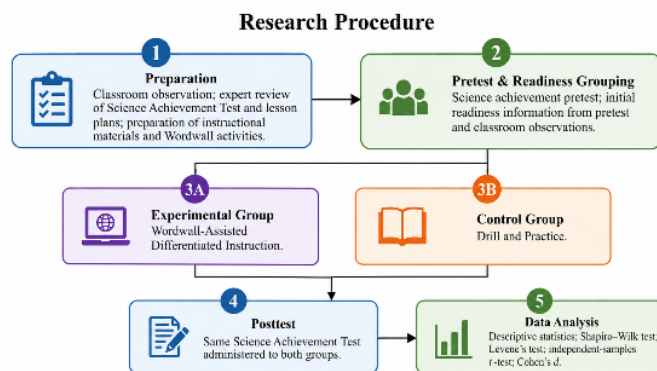


Figure 1. Research Procedure of the Quasi-Experimental Study

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.

Data Collection Techniques

Data were collected using a Science Achievement Test and a Classroom Observation Sheet. The Science Achievement Test was administered as a pretest and posttest to measure students' science learning outcomes on the Solar System topic. The Classroom Observation Sheet was used to monitor the implementation of the instructional intervention (Folwell et al., 2025).

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. The items assessed students' conceptual understanding, application, and problem-solving related to the Solar System topic (Karimian & Chahartangi, 2024).

The Classroom Observation Sheet was developed based on the differentiated instruction framework and was used to document the implementation of the instructional procedures, including the adaptation of learning activities and the use of Wordwall in the experimental group.

Instrument Validity and Reliability

The research instruments were evaluated by three experts to establish content validity. The Science Achievement Test was assessed using Aiken's *V*, while its internal consistency was examined using the Kuder–Richardson Formula 20 (KR-20). The Classroom Observation Sheet was also reviewed by experts to assess its content validity and was used to monitor implementation fidelity (Bi et al., 2024). The Science Achievement Test obtained an Aiken's *V* value of 0.91 and a KR-20 reliability coefficient of 0.82, indicating satisfactory content validity and internal consistency. The Classroom Observation Sheet obtained an Aiken's *V* value of 0.90. These results supported the use of the instruments for data collection in the present study.

Data Analysis

Data were analyzed using descriptive and inferential statistics. Descriptive statistics included the mean, standard deviation, minimum, and maximum scores for the pretest and posttest results. Before inferential analysis, the normality of the data was examined using the Shapiro–Wilk test, and homogeneity of variance was assessed using Levene's test. These procedures were conducted to determine whether the assumptions for the independent-samples *t*-test were adequately met.

The primary hypothesis was tested using an independent-samples *t*-test to compare the posttest science learning outcomes of the experimental and control groups. Statistical significance was evaluated at the 0.05 level. Cohen's *d* was calculated to estimate the magnitude of the difference between the two groups and to provide an indication of the practical significance of the intervention.

No regression analysis was conducted because student attention was removed from the research model and is no longer treated as a study variable. N-gain analysis was also not included as a primary inferential procedure because the research hypothesis concerns the difference in posttest science learning outcomes between the two groups.

Ethical Considerations

Because the participants were elementary school students, ethical procedures were applied before data collection. Permission to conduct the study was obtained from the participating schools. Participation was voluntary, and students' research data were treated confidentially.

Research Instruments

Two instruments were employed in this study: (1) a Science Achievement Test and (2) 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' science learning outcomes on the Solar System topic.

The Classroom Observation Sheet was developed based on the Differentiated Instruction Framework to monitor instructional implementation, student participation, and implementation fidelity during the intervention. Prior to implementation, the instruments were evaluated by three experts to establish content validity using Aiken's *V*. The Science Achievement Test was further tested for reliability using KR-20. The Classroom Observation Sheet was evaluated for inter-rater agreement. The results indicated that the instruments demonstrated acceptable validity and reliability for use in the study. A summary of the research instruments is presented in Table 3.

Table 3. Research Instruments

Instrument	Source / Adapted From	Construct Measured	Indicators	Items	Validity (Aiken's <i>V</i>)	Reliability
Science Achievement Test	Merdeka Curriculum (Grade VI IPAS); Bloom's Revised Taxonomy	Science learning outcomes	Conceptual understanding, application, and problem-solving	20 (MCQ)	0.91	KR-20 = 0.82
Classroom Observation Sheet	Differentiated Instruction Framework	Implementation fidelity	Instructional implementation and student participation	Checklist	0.90	Inter-rater agreement

Table 3 summarizes the instruments used to collect data in the study. The Science Achievement Test was administered as both the pretest and posttest to measure students' science learning outcomes before and after the intervention. The Classroom Observation Sheet was used during the intervention to monitor the implementation of differentiated learning activities, the use of Wordwall in the experimental group, adherence to the planned instructional sequence, and student participation. The observation data were used to assess implementation fidelity and 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. Cohen's *d* was calculated to estimate the magnitude of the difference between the two groups. Statistical significance was determined at the 0.05 level (Carolina et al., 2026).

Conceptual Framework of the Study

The conceptual framework of this study proposes that Wordwall-assisted differentiated instruction can support students' science learning outcomes by integrating differentiated learning activities with interactive digital learning. Differentiated instruction accommodates differences in students' readiness by adapting learning content, learning processes, and learning tasks. Wordwall complements the differentiated instructional process by providing interactive quizzes, matching activities, and game-based exercises that allow students to practice science concepts and receive immediate feedback.

The framework is grounded in Differentiated Instruction Theory and Constructivist Learning Theory. Differentiated Instruction Theory emphasizes the adaptation of learning experiences to students' learning needs and readiness, while Constructivist Learning Theory views learning as an active process in which students construct understanding through meaningful learning experiences. The integration of these principles with Wordwall-based activities is expected to support improved science learning outcomes in the Solar System topic (Lehtinen et al., 2025).

RESULTS

Descriptive Statistics of Science Learning Outcomes

Descriptive statistics were first calculated to summarize students' science learning outcomes before and after the instructional intervention.

Table 4. Descriptive Statistics of Students' Science Learning Outcomes

Group	N	Pretest <i>M</i>	Pretest <i>SD</i>	Posttest <i>M</i>	Posttest <i>SD</i>
Wordwall-assisted Differentiated Instruction	16	46.35	9.93	81.56	4.57
Drill and Practice	16	46.04	8.63	66.67	4.08

Table 4 shows that the experimental and control groups had similar descriptive pretest means, with mean scores of 46.35 and 46.04, respectively. Following the instructional intervention, the experimental group obtained a mean posttest score of 81.56, whereas the control group obtained a mean posttest score of 66.67. The descriptive results therefore show a higher posttest mean for the group receiving Wordwall-assisted differentiated instruction. However, similarity in descriptive pretest means alone does not establish baseline equivalence. Therefore, pretest scores were statistically controlled in the subsequent ANCOVA to provide an adjusted comparison of posttest science learning outcomes.

Preliminary Assumption Tests

Before conducting ANCOVA, preliminary assumption tests were performed to examine the suitability of the data for parametric analysis.

Normality

Table 5. 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	0.200	0.05	Normal

Table 5 indicates that the significance values for the pretest and posttest scores in both groups were greater than 0.05. Therefore, the scores did not significantly deviate from a normal distribution, indicating that the normality assumption was satisfied.

Homogeneity of Variance

Table 6. Homogeneity Test Results

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

Table 6 shows that the significance value of Levene's test exceeded 0.05. Therefore, the variances of the experimental and control groups were considered homogeneous.

Homogeneity of Regression Slopes

Because ANCOVA was used as the primary inferential analysis, the homogeneity of regression slopes was also examined by testing the interaction between pretest scores and instructional group.

Table 7. Test of Homogeneity of Regression Slopes

Source	SS	df	F	p
Pretest × Group	43.255	1	2.365	.135

The interaction between pretest scores and instructional group was not statistically significant, $F(1, 28) = 2.365$, $p = .135$. Because $p > .05$, there was no statistically significant evidence that the relationship between pretest and posttest scores differed between the two instructional groups. Therefore, the assumption of homogeneity of regression slopes was considered satisfied, supporting the use of the ANCOVA model without an interaction term.

Analysis of Covariance

Because the study employed a pretest–posttest control group design, an analysis of covariance (ANCOVA) was conducted to examine the effect of instructional condition on posttest science learning outcomes while statistically controlling for pretest scores. Pretest scores were entered as the covariate, instructional group as the fixed factor, and posttest science learning outcomes as the dependent variable. The ANCOVA results are presented in Table 8.

Table 8. ANCOVA Results for Science Learning Outcomes

Source	SS	df	MS	F	p	Partial η^2
Corrected Model	1783.38	2	891.69	46.55	< .01	.76
Pretest	8.29	1	8.29	0.43	.51	.01
Group	1770.34	1	1770.34	92.43	< .01	.76
Error	555.42	29	19.15	—	—	—
Corrected Total	2338.80	31	—	—	—	—

The ANCOVA results showed that pretest scores did not have a statistically significant effect on posttest science learning outcomes after controlling for instructional group, $F(1, 29) = 0.43$, $p = 0.51$, partial $\eta^2 = .015$. In contrast, instructional group had a statistically significant effect on posttest science learning outcomes after controlling for pretest scores, $F(1, 29) = 92.434$, $p < .001$, partial $\eta^2 = .761$. The partial η^2 value of 0.761 indicates that a substantial proportion of the variance in adjusted posttest science learning outcomes was associated with instructional group within the ANCOVA model. The result provides evidence of a statistically significant difference in science learning outcomes between students receiving Wordwall-assisted differentiated instruction and those receiving the Drill and Practice method after controlling for pretest scores.

Adjusted Posttest Means

To further interpret the ANCOVA result, adjusted posttest means and their confidence intervals were examined.

Table 9. Adjusted Posttest Means by Group

Group	N	Observed Posttest <i>M</i>	Adjusted <i>M</i>	SE	95% CI
Wordwall-assisted Differentiated Instruction	16	81.56	81.55	1.09	79.32–83.79
Drill and Practice	16	66.67	66.68	1.09	64.44–68.91

After adjustment for pretest scores, the Wordwall-assisted differentiated instruction group had an adjusted posttest mean of 81.55 (SE = 1.09, 95% CI [79.32, 83.79]), whereas the Drill and Practice group had an adjusted posttest mean of 66.68 (SE = 1.09, 95% CI [64.44, 68.91]). The adjusted means show that the difference between the groups remained evident after statistically controlling for pretest scores.

Hypothesis Testing

The research hypothesis stated that students receiving Wordwall-assisted differentiated instruction would achieve higher science learning outcomes than students receiving the Drill and Practice method. Based on the ANCOVA results, the instructional group had a statistically significant effect on posttest science learning outcomes after controlling for pretest scores, $F(1, 29) = 92.434$, $p < .001$, partial $\eta^2 = .761$. The adjusted posttest mean was 81.55 for the Wordwall-assisted differentiated instruction group and 66.68 for the Drill and Practice group. Therefore, the statistical analysis provides evidence of a significant difference in adjusted posttest science learning outcomes between the two instructional conditions.

DISCUSSION

Results from the ANCOVA indicated a statistically significant effect of instructional group on students' science learning outcomes, $F(1, 29) = 92.434$, $p < .001$, partial $\eta^2 = .761$. Students who received Wordwall-assisted differentiated instruction obtained a higher adjusted posttest mean ($M = 81.55$, SE = 1.09, 95% CI [79.32, 83.79]) than students who received the Drill and Practice method ($M = 66.68$, SE = 1.09, 95% CI [64.44, 68.91]). Descriptive results also showed higher posttest performance in the experimental group ($M = 81.56$, SD = 4.57)

than in the control group ($M = 66.67$, $SD = 4.08$). After controlling for pretest scores, the significant group effect indicates that the instructional condition was associated with differences in science learning outcomes within the present sample.

Differentiated Instruction Theory provides a relevant framework for interpreting the observed difference. Differentiated instruction adapts learning content, learning processes, and learning tasks according to students' readiness and learning needs. Within the present intervention, students' readiness information was considered in organizing differentiated learning activities, while Wordwall provided interactive activities such as quizzes, matching exercises, Gameshow Quiz, and Random Wheel. Such an instructional arrangement can provide varied opportunities for students to engage with Solar System concepts through activities that correspond to different levels of readiness. Consequently, learning activities were not limited to a single instructional pathway, but incorporated adaptations within the broader instructional process.

Wordwall functioned as a complementary digital medium rather than as an independent instructional treatment. Interactive quizzes and game-based activities provided opportunities for students to practice concepts and receive immediate feedback during learning activities. Immediate feedback can help students recognize errors and reinforce correct responses during practice. Within a differentiated instructional framework, interactive digital activities may therefore complement adaptations in content, process, and learning tasks. However, the present design does not allow the individual contribution of Wordwall to be separated from the contribution of differentiated instruction.

Constructivist Learning Theory also provides a theoretical perspective for understanding the learning process. Learning occurs through active involvement in meaningful experiences, allowing students to develop and strengthen conceptual understanding through interaction with learning tasks. Differentiated activities combined with interactive Wordwall exercises created opportunities for students to work with Solar System concepts through varied learning experiences. Such activities may support students in constructing understanding through practice, problem solving, feedback, and reflection. Because the study did not directly measure the underlying cognitive processes, however, the constructivist explanation should be regarded as a theoretical interpretation rather than direct empirical evidence of the mechanism responsible for the observed effect.

Previous research provides contextual support for the present findings. (Saputri et al., 2024; Pratiwi et al., 2025) and (Hidayah et al., 2025) reported findings concerning the implementation of differentiated learning approaches and their relationship with student learning outcomes. Research by (Yustin et al., 2025), (Sari et al., 2024) and (Rifayanti et al., 2024) also provides evidence concerning the use of digital or interactive learning media to support learning activities. Findings from the present study extend such evidence by examining the deliberate integration of Wordwall with differentiated instruction in Grade VI IPAS learning, particularly on the Solar System topic within the Merdeka Curriculum. Rather than examining digital media and differentiated instruction as unrelated instructional practices, the present study considers both components as a combined instructional package.

Several methodological considerations are important when interpreting the findings. First, the intervention consisted of two interconnected components: differentiated instruction and Wordwall-assisted activities. Consequently, the observed difference represents the effect of the combined instructional package compared with the Drill and Practice method. The research design cannot determine whether the observed outcome was primarily attributable to differentiated instruction, Wordwall, or the interaction between both components. Future studies could address this issue by comparing differentiated instruction with and without Wordwall or by including additional treatment conditions.

Second, the use of intact classroom groups from two schools introduces the possibility of school- and teacher-related influences. Differences in classroom context, instructional practices, available resources, or other school characteristics may have contributed to the observed outcomes. Consequently, the findings should not be interpreted as evidence that the instructional package would produce the same magnitude of effect across all elementary schools. Larger studies involving multiple schools and teachers would provide stronger evidence concerning the consistency of the findings across educational contexts.

The ANCOVA results also provide an important statistical consideration. The pretest covariate was not statistically significant, $F(1,29) = 0.433$, $p = .516$, partial $\eta^2 = .015$. A nonsignificant covariate effect should not be interpreted as definitive evidence of complete baseline equivalence between groups. Descriptive pretest means were relatively similar, with $M = 46.35$ ($SD = 9.93$) for the experimental group and $M = 46.04$ ($SD = 8.63$) for the control group. ANCOVA nevertheless provides an appropriate adjusted comparison by statistically accounting for pretest scores when examining differences in posttest outcomes.

The assumption of homogeneous regression slopes was also supported because the interaction between pretest scores and instructional group was not statistically significant, $F(1,29) = 2.365$, $p = .135$. Satisfaction of this assumption supports the use of ANCOVA for comparing adjusted posttest means across instructional groups. Variance homogeneity was likewise supported by the nonsignificant Levene's test, while the Shapiro-Wilk results indicated acceptable normality for the pretest and posttest scores. Collectively, the assumption tests provide statistical support for interpreting the ANCOVA results.

The partial eta squared value for the instructional group effect ($\eta^2 = .761$) indicates a substantial effect within the present sample. Interpretation of the magnitude should nevertheless remain contextual because the study involved only 32 students distributed across two intact classroom groups, and no a priori power analysis was conducted. A substantial effect observed in a small classroom-based sample does not by itself establish the same magnitude of effect in a larger or more diverse population. Replication with larger samples, multiple schools, and more classrooms would strengthen the external validity of the findings.

From a pedagogical perspective, the findings suggest that Wordwall can be positioned as a supporting medium within differentiated instruction rather than as a replacement for systematic instructional planning. Effective implementation requires teachers to identify differences in students' readiness and subsequently adapt learning content, processes, and tasks. Wordwall can then be incorporated to provide interactive practice, formative feedback, and varied learning activities. Such integration is particularly relevant for science topics that involve conceptual understanding and require repeated practice, including the Solar System topic examined in the present study.

The findings also have implications for implementation of the Merdeka Curriculum, which emphasizes learning that responds to students' needs and supports meaningful classroom experiences. Integration of differentiated instruction with interactive digital activities provides one possible approach for translating such principles into classroom practice. Nevertheless, broader implications for educational quality or large-scale curriculum effectiveness should be interpreted cautiously because the present study measured science learning outcomes within a specific Grade VI classroom context rather than broader educational indicators.

Overall, the findings provide empirical support for an association between Wordwall-assisted differentiated instruction and higher science learning outcomes compared with the Drill and Practice method after adjustment for pretest scores. The significant ANCOVA result and substantial partial eta squared indicate a clear difference between instructional groups within the study sample. At the same time, the quasi-experimental design, small sample, intact classroom structure, school and teacher context, and combined nature of the intervention limit the extent to which the findings can be attributed to individual treatment components or generalized to broader populations. Further research involving larger and more diverse samples, multiple schools and teachers, and designs that separate the effects of Wordwall from differentiated instruction would provide stronger evidence regarding the effectiveness and mechanisms of the integrated instructional approach.

CONCLUSION

Results from the present study indicate that Wordwall-assisted differentiated instruction was associated with higher science learning outcomes than the Drill and Practice method among the 32 Grade VI students included in the study. ANCOVA results showed a statistically significant effect of instructional group after controlling for pretest scores, $F(1,29) = 92.434$, $p < .001$, partial $\eta^2 = .761$. Students in the experimental group obtained an adjusted posttest mean of 81.55 ($SE = 1.09$, 95% CI [79.32, 83.79]), whereas students in the control group obtained an adjusted posttest mean of 66.68 ($SE = 1.09$, 95% CI [64.44, 68.91]). Within the scope of the 32-student sample and four-session intervention, these findings provide empirical support for the potential use of Wordwall-assisted differentiated instruction to support science learning outcomes.

Integration of Wordwall with differentiated instruction contributes to research on technology-supported learning by positioning interactive digital activities as a complementary component of differentiated classroom practice. Adaptation of learning content, processes, and tasks according to students' readiness was combined with Wordwall activities, including quizzes, matching activities, Gameshow Quiz, and Random Wheel. Such integration provides a possible approach for incorporating interactive digital activities into differentiated science instruction. Because the intervention consisted of a combined instructional package, however, separate effects attributable to Wordwall, differentiated instruction, or the interaction between both components cannot be determined from the present design.

Practical implications indicate that elementary teachers may consider Wordwall as a supporting medium when implementing differentiated science instruction. Effective implementation requires attention to students' readiness and appropriate adaptation of learning activities rather than reliance on digital media alone. Interactive Wordwall activities can complement differentiated learning by providing opportunities for practice and feedback. Broader claims concerning educational quality should be considered potential implications rather than direct empirical findings because the present study specifically examined science learning outcomes.

Several limitations should be considered when interpreting the findings. The study involved 32 Grade VI students from two elementary schools, comprising 16 students in the experimental group and 16 students in the control group. Intact classroom groups and two school contexts introduce the possibility of school- and teacher-related influences on the observed results. The relatively small sample, quasi-experimental design, four-session intervention, and combined treatment structure also limit generalizability and prevent separate attribution of the observed effect to individual treatment components. No a priori power analysis was conducted. Future research should involve larger samples across multiple schools and teachers, longer intervention periods, and research designs capable of distinguishing the individual and combined contributions of differentiated instruction and

Wordwall. Additional learning outcomes may also be examined when explicitly included in the research objectives and measured using appropriate instruments.

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AUTHOR CONTRIBUTION STATEMENT

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

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