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Students' mathematical conceptual understanding following deep learning supported by Wordwall: A one-group pretest–posttest study

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Students' mathematical conceptual understanding following deep learning supported by Wordwall: A one-group pretest–posttest study

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ABSTRACT

Students need to acquire mathematical conceptual understanding to be able to explain, relate, and apply mathematical ideas in different problem situations. However, the learning of mathematics at public Junior High School (SMP Negeri) 1 Kenduruan is still limited to the use of interactive digital media. Previous studies on the integration of deep learning supported by Wordwall to improve mathematical conceptual understanding have been limited. The aim of this study was to analyze the changes in the mathematical conceptual understanding of eighth-grade students after being given deep learning supported by Wordwall. A quantitative pre-experimental, one-group pretest-posttest design was used. The participants were 31 students of Class VIII-E selected using purposive sampling. The intervention was delivered in five sessions. The intervention was delivered in five sessions on cubes and rectangular prisms and consisted of one pretest, three deep learning sessions with Wordwall activities (Group Sort, Spin the Wheel, and Quiz), and one posttest. Data were collected using a mathematical conceptual understanding test and analyzed using descriptive statistics, the Shapiro-Wilk test, paired-samples t-test, and N-Gain analysis. The average score increased from 33.629 on the pretest to 74.677 on the posttest. A paired-samples t-test showed that there was a statistically significant difference, $t(30) = -21.282$, $p < .001$. The average N-Gain score was 0.625, which was categorized as moderate. These findings indicate enhanced conceptual understanding of mathematics following the intervention. But a one-group design without a control group limits causal interpretation. Larger samples, control groups, and broader learning contexts should be included in future studies.

Keywords: Conceptual Understanding, Deep Learning, Mathematics Education, Wordwall Interactive Platform

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INTRODUCTION

Conceptual understanding is important in learning mathematics. Students who have a good understanding of mathematical concepts can link different concepts, understand their underlying meanings, and use them appropriately in different contexts. Hence, mathematics education should be aimed not only at the ultimate learning results but also at the development of students' conceptual understanding. This emphasis is also reflected in the Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 22 of 2016 concerning the Standards for Primary and Secondary Education Processes, which states that learning activities must facilitate students in understanding, connecting, and applying concepts accurately. Thus, it is important to master mathematical concepts to support students' success in learning mathematics.

The level of student participation in the learning process is an important factor in the success of learning mathematics. This kind of engagement is not only limited to active participation in learning activities but also comprises cognitive, emotional, and social dimensions that together facilitate the achievement of learning outcomes (Bond et al., 2021; Zainuddin, Shujahat, et al., 2020). Based on the observation of the learning process in class VIII of Junior High School (SMP Negeri) 1 Kenduruan, the learning process was dominated by the lecture process. Most of the learning activities were centered around teacher explanations. Generally, students were able to solve problems that were similar to the examples given but had difficulty with problems presented in unfamiliar forms or contexts. The learning media were mainly through whiteboard and textbook instructions, and interactive digital technology was not optimally used. This indicates that there is a great demand for innovation in the learning process. The appropriate instructional innovation could increase students' engagement and conceptual understanding. However, when learning is confined to procedural knowledge, students' conceptual understanding is often poor. Students therefore may have difficulties in the application of mathematical concepts to new situations (Bond et al., 2021).

Implementing instructional practices that support engaging, relevant, and student-centered learning is necessary to improve the quality of mathematics education. Students can get a richer conceptual knowledge of mathematics by participating in activities that entail idea exploration, discussion, and problem-solving. The quick development of educational technology gives teachers the chance to use a variety of interactive digital media, which can improve students' motivation, focus, and active engagement and make learning more successful, interesting, and pleasurable.

One pedagogical approach that can be implemented is deep learning, which encourages students to construct conceptual understanding, connect prior knowledge with new information, apply concepts in different contexts, and reflect on their thinking processes (Fullan et al., 2018). In this study, deep learning is operationalized through mindful, meaningful, and joyful learning, which respectively emphasize awareness of learning processes, connections between concepts and prior knowledge, and engaging learning experiences supported by interactive activities such as Wordwall (Chotimah et al., 2025). Unlike active learning, gamification, or general student-centered instruction, deep learning places greater emphasis on deeper conceptual processing, reflection, and knowledge transfer rather than participation or engagement alone. Previous studies have also indicated that this approach may support higher-order thinking, active participation, and mathematical understanding (Maulidya et al., 2025; Mutmainnah et al., 2025).

Beyond the selection of an appropriate instructional approach, the integration of interactive learning media is equally important in enhancing the quality of mathematics instruction. One of the digital learning platforms that can help in this process is Wordwall. It offers a variety of interactive activities, such as quizzes, educational games, and practice tasks. Its use in the classroom can make learning mathematics more interesting and dynamic, promoting increased motivation, participation, and active involvement among students. Previous studies have also indicated that Wordwall positively contributes to students' learning motivation, engagement, and conceptual understanding (Qomaria et al., 2024; Ma'arif et al., 2025). But the success of digital media is largely dependent on the pedagogical approach that supports its delivery. Hence, interactive media must be integrated with learning strategies that emphasize conceptual understanding so that technology can contribute more effectively to improving learning outcomes.

Previous studies have reported positive outcomes from deep learning and Wordwall; however, their contexts, participants, and measured outcomes differ from those examined in the present study. Studies on deep learning have generally emphasized higher-order thinking and student participation, whereas several Wordwall studies have been conducted in subjects such as IPAS and religious education and have primarily focused on achievement, motivation, or engagement rather than mathematical conceptual understanding (Maulidya et al., 2025; Rosyid & Alwi, 2025). Consequently, the research gap lies not merely in combining deep learning with Wordwall, but in examining how Wordwall-based activities are systematically integrated into mindful, meaningful, and joyful learning processes to support junior high school students in constructing, connecting, applying, and reflecting on mathematical concepts. This study therefore contributes a mathematics-specific implementation of deep learning supported by Wordwall and examines changes in students' conceptual understanding through a one-group pretest-posttest design.

Aimed at eighth-grade students at SMP Negeri 1 Kenduruan, this research seeks to examine changes in students' mathematical conceptual understanding following deep learning supported by Wordwall interactive media. It is anticipated that the results will contribute to the development of more innovative mathematics instructional practices. Moreover, this study could be a resource for teachers to enhance the integration of digital technologies in classroom instruction to make mathematics learning more enjoyable, meaningful, and effective.

METHOD

The study employed a quantitative approach with a pre-experimental research design: one-group pre-test and post-test. The research was carried out in Junior High Sch

ool (SMP Negeri) 1 Kenduruan in the second semester of the academic year 2025/2026. This design was used to find out the change in students' mathematical conceptual understanding before and after the implementation of deep learning assisted by Wordwall interactive media. As the study was uncontrolled, changes observed are not necessarily evidence that the intervention was responsible for the improvement.

The population of this study was all the eighth graders of SMP Negeri 1 Kenduruan, which consisted of 188 students. The sample was selected purposively; Class VIII-E, comprising 31 students were chosen as the participants for the study. This class was chosen because it had similar characteristics of mathematical achievement to the other eighth-grade classes, had no previous experience with Wordwall-supported deep learning, and was available to participate during the five meeting intervention.

The research procedure was divided into three stages: preparation, implementation, and completion. During the preparation phase, the researcher prepared the learning materials, lesson plans, and research instrument. The intervention consisted of five sessions on cubes and rectangular prisms. The first meeting was used for the pretest. The second to fourth meetings implemented deep learning supported by Wordwall interactive media. The learning process emphasized mindful, meaningful, and joyful learning through concept exploration, discussion, reflection, and problem-solving activities. Wordwall was integrated into each learning session through different interactive activities: Group Sort in the second meeting to classify and organize mathematical concepts, Spin the Wheel in the third meeting to stimulate concept recall and discussion, and Quiz in the fourth meeting to provide interactive practice and formative assessment. The fifth meeting was used for the posttest to measure changes in students' mathematical conceptual understanding following the intervention.

The research instrument used is known as a mathematical conceptual understanding test as a pretest and posttest. The instrument was a 10-item essay on the mathematical subject of cubes and rectangular prisms. The items were developed based on the conceptual understanding indicators proposed by (Widiarti et al., 2022), including restating a concept, identifying examples and non-examples, classifying objects based on conceptual properties, representing concepts in various mathematical forms, and applying or selecting appropriate procedures and operations. Each item was rated using a pre-established scoring rubric, and the total score was converted to a scale of 0-100. Expert validation was performed prior to application of the instrument to evaluate its content relevance, indicator alignment, clarity of language, and item construction. The instrument was used in the study after it was revised based on the validators' suggestions.

The data for the research were students' pretest and posttest scores and were analyzed using IBM SPSS Statistics version 25. Descriptive statistics were used to present the data, and the Shapiro-Wilk test was used to check the normality of the score distribution. If the data met the normality assumption, a paired-samples t-test was conducted; otherwise, the Wilcoxon signed-rank test was used as a nonparametric alternative. Statistical decisions were made using a significance level of 0.05.

To examine the magnitude of students' improvement following the intervention, an N-Gain analysis was conducted. The N-Gain scores were interpreted according to Hake (1998), with improvement categorized as low, moderate, or high. In this study, the N-Gain analysis was used to describe the degree of improvement in students' mathematical conceptual understanding rather than to establish the causal effectiveness of the intervention.

RESULT

This section shares the obtained results of the analyses formulated to inspect the effectiveness of deep learning with the support of Wordwall interactive media in improving students' mathematical conceptual learning. Several stages were involved in conducting the analysis. It started with a descriptive statistical analysis, continued with a normality test, and proceeded to hypothesis testing using the Paired Samples t-test. An N-Gain analysis was also performed to determine how much students' mathematical conceptual understanding had improved following the learning intervention.

Descriptive Statistics of Mathematical Conceptual Understanding

To present a clear picture of how students' mathematical conceptual understanding changed prior to and following the implementation of deep learning supported by Wordwall interactive media, descriptive statistical analysis was carried out. A conclusion of the results are displayed in Table 1 as a basis for identifying changes in students' performance following the intervention.

Table 1. Descriptive Statistics of Pretest and Posttest Scores

Variable	N	Mean	Standard Deviation	Minimum	Maximum
Pretest	31	33.629	11.2886	12.5	57.5
Posttest	31	74.677	11.4153	55.0	97.5

Table 1 shows that prior to the intervention, students' mathematical conceptual understanding, obtained through the pretest, reached an average score of 33.629, with a standard deviation of 11.2886, ranging from 12.5 to 57.5. Following the implementation of deep learning assisted by Wordwall interactive media, this average rose to 74.677, with a standard deviation of 11.4153, while the posttest results ranged from a minimum of 55.0 to a maximum of 97.5. Following the implementation of the learning intervention, students' mathematical conceptual understanding appears to have improved, as reflected by the difference observed between their pretest and posttest results.

Results of the Normality Test

The research data were analyzed to see if they satisfied the normality assumption before the hypothesis test was carried out. The Shapiro-Wilk test was employed to determine whether the difference scores were normal because the study included 31 students. Each student's difference score for the paired-samples analysis was determined by deducting the pretest score from the posttest score (posttest − pretest). Consequently, rather than concentrating on the pretest and posttest scores independently, the normality assessment examined the distribution of the difference scores.

Table 2. Results of the Shapiro–Wilk Normality Test

Variable	**Statistic**	**df**	**Sig.**
Difference score	0.948	31	0.135

The Shapiro-Wilk test yielded a statistic of 0.948 with a significance value of 0.135 for the difference scores, as seen in Table 2. The difference scores were regarded as normally distributed since the significance value was higher than 0.05. Consequently, the paired-samples analysis's normality assumption was satisfied.

In addition to the Shapiro–Wilk test, the distribution of the difference scores was examined graphically using a normal $Q-Q$ plot. As shown in Figure 1, most of the observed values were located relatively close to the reference line, with some deviations at the lower and upper ends of the distribution. This graphical assessment provided additional support for the normality of the difference scores.

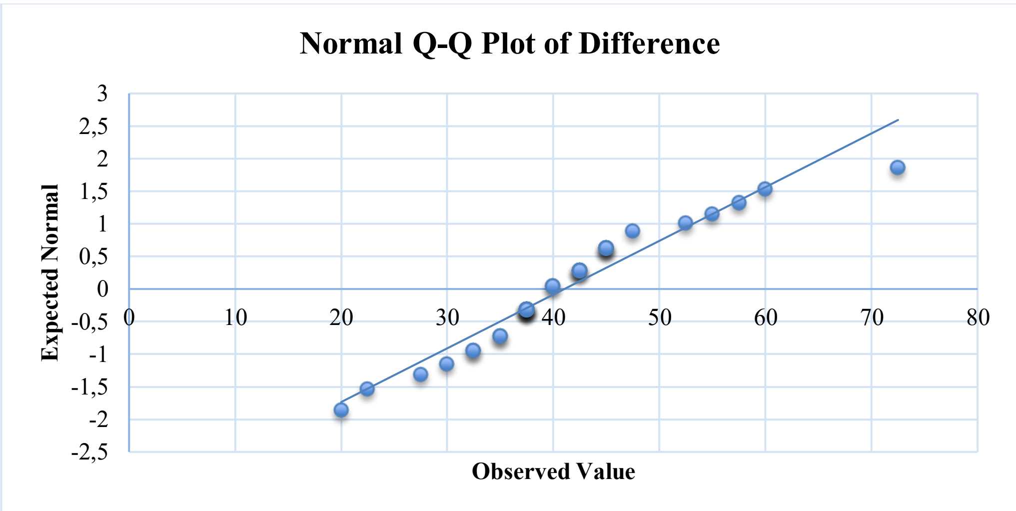

Figure 1. Normal $\boldsymbol{Q-Q}$ Plot of the Difference Scores from SPSS here

When combined, the graphical analysis and the Shapiro-Wilk test (W=0.948, p=0.135) showed that the difference scores satisfied the normality assumption. In order to determine whether there was a significant difference between the students' arithmetic conceptual comprehension scores before and after the intervention, a paired-samples t-test was deemed appropriate.

Results of Hypothesis Testing

The hypothesis testing was conducted to assess whether there was a significant difference in students' arithmetic conceptual comprehension scores before and after the intervention. Based on the normality evaluation, the difference scores were normally distributed; consequently, a paired-samples t-test was utilized to compare the pretest and posttest scores. The hypotheses were formulated as follows:

$H_0 : \mu d = 0$

$H_1 : \mu d \neq 0$

Where μd represents the mean difference between the posttest and pretest scores. H_0 states that there is no difference in students' mathematical conceptual understanding scores before and after the intervention, whereas H_1 states that there is a difference in students' mathematical conceptual understanding scores before and after the intervention.

A paired-samples t-test was undertaken to investigate whether there was a significant difference between students' arithmetic conceptual comprehension scores before and after the intervention. The descriptive data are reported in Table 3.

Table 3. Descriptive Statistics of the Paired Scores

Measurement	N	Mean	Std. Deviation
Pretest	31	33.629	11.2886
Posttest	31	74.677	11.3153

As indicated in Table 3, the mean score increased from 33.629 in the pretest to 74.677 in the posttest. Thus, the descriptive data demonstrate an increase of 41.048 points in students' arithmetic conceptual comprehension scores following the intervention.

Table 4. Results of the Paired-Samples t-Test

Comparison	Mean Difference	t	df	Sig. (2-tailed)
Pretest – Posttest	-41.048	-21.282	30	< .001

Students' pretest and posttest scores differed statistically significantly, as seen in Table 4, according to the paired-samples t-test ($t(30) = -21.282$, $p < .001$). The posttest scores were greater than the pretest scores, as indicated by the mean difference of -41.048. As a result, H_1 was accepted and H_1 was rejected. These results demonstrate a substantial difference between the pretest and posttest results for students' arithmetic conceptual knowledge.

N-Gain Analysis

To determine how much students' conceptual understanding of mathematics improved during a deep learning session supported by Wordwall interactive media, N-Gain analysis was developed. The distribution of improvement levels generated from the designated categories and the average N-Gain score are presented in this analysis. Tables 5 and 6 present an overview of the findings.

Table 5. Average N-Gain Score of Mathematical Conceptual Understanding

Statistic	Value
Number of Students	31
Average N-Gain Score	0.625

Category	Moderate

As presented in Table 5, the average N-Gain score was 0.625, which belongs to the moderate category. This result indicates that the students' mathematical conceptual understanding increased moderately from the pretest to the posttest. The N-Gain score reported is the average of the individual N-gain scores obtained for the 31 students, not an N-Gain that was calculated from the class mean scores.

Table 6. Distribution of N-Gain Categories for Mathematical Conceptual Understanding

Category	Frequency	Percentage (%)
High	9	29.03
Moderate	22	70.97
Low	0	0.00
Total	31	100

Nine students (29.03%) were categorized in the high category, whereas 22 students (70.97%) received N-Gain values in the intermediate range, as indicated in Table 6. Not a single student received an N-Gain score in the low range. According to these results, the majority of students' conceptual grasp of mathematics improved to a moderate degree between the pretest and the posttest.

The pretest and posttest findings were further examined in accordance with each conceptual-understanding indicator to give a more thorough account of the shifts in students' mathematical conceptual understanding. Table 7 displays the findings.

Table 7. Pretest and Posttest Results by Indicator of Mathematical Conceptual Understanding

Indicator of Mathematical Conceptual Understanding	Pretest (%)	Posttest (%)	Improvement (percentage points)
Restating a concept	43.55	75.40	31.85
Providing examples and non-examples	65.32	81.05	15.73
Classifying objects based on concept properties	39.11	78.23	39.11
Representing concepts mathematically	18.15	73.39	55.24
Selecting and applying procedures or operations	2.02	65.32	63.31

As presented in Table 7, all five indicators of mathematical conceptual understanding showed improvement from the pretest to the posttest. The greatest improvement was observed in selecting and applying procedures or operations, which increased by 63.31 percentage points, from 2.02% in the pretest to 65.32% in the posttest. This was followed by representing concepts mathematically, which increased by 55.24 percentage points, from 18.15% to 73.39%. Classifying objects based on concept properties increased by 39.11 percentage points, while restating a concept increased by 31.85 percentage points. Meanwhile, providing examples and non-examples showed the smallest improvement, increasing by 15.73 percentage points, from 65.32% to 81.05%.

Overall, the results show improvement across all five indicators of mathematical conceptual understanding, although the magnitude of improvement varied among the indicators. The largest improvement occurred in selecting and applying procedures or operations, whereas providing examples and non-examples showed the smallest increase. These indicator-level findings provide a more detailed description of the changes in students' mathematical conceptual understanding between the pretest and posttest.

DISCUSSION

According to earlier research, deep learning can help students have more context-based and meaningful learning experiences (Fullan et al., 2018). Students' arithmetic conceptual-understanding scores in the current study improved from a mean of 33.629 in the pretest to 74.677 in the posttest. A statistically significant difference between the two values was found using a paired-samples t-test ($t(30) = -21.282$, $p < .001$). Furthermore, the average N-Gain score was 0.625, falling into the moderate range. Although the overall magnitude of improvement was low, these data show a significant shift in students' test performance between the pretest and posttest.

A possible explanation for the substantial improvement in selecting and applying procedures or operations relates to the interactive nature of the learning activities. Wordwall provides digital activities in which questions and mathematical tasks can be presented in interactive and game-based formats, accompanied by immediate feedback (Putri et al., 2024; Zainuddin, Chu, et al., 2020). Such features may provide opportunities for students to practice mathematical tasks and apply concepts in problem-solving situations. And the previous research has shown that digital learning media can improve students' learning results and conceptual understanding (Balalle, 2024). However, this interpretation is only theoretical because, in the present study, no process data were collected to provide evidence on how the students interacted with the activities or which specific features of Wordwall contributed to their improvement.

In addition, significant progress in the representation of concepts mathematically was observed, with an increase of 55.24 percentage points from 18.15% in the pretest to 73.39% in the posttest. Mathematical conceptual understanding is not only about doing procedures but also about understanding, representing, linking, and applying mathematical concepts (Widiarti et al., 2022). Thus, the increase in this indicator indicates a significant change in the performance of students in tasks with mathematical representations. Theoretically, such development can be supported through interactive digital activities which expose students to mathematical tasks in various formats. However, because the present study relied on test scores alone, the specific learning processes underlying this improvement cannot be directly determined.

By contrast, providing examples and non-examples showed the smallest increase, at 15.73 percentage points, from 65.32% to 81.05%. This indicator also had the highest pretest percentage among the five components. The smaller gain may therefore partly reflect students' relatively strong initial performance, leaving less room for further improvement. In comparison, representing concepts mathematically and selecting and applying procedures or operations began with substantially lower pretest percentages and subsequently showed larger gains. Such variation indicates that improvement was not uniform across the different components of mathematical conceptual understanding.

Differences among the indicators may also help explain why the overall N-Gain remained in the moderate category. Although all five components improved, the extent of improvement varied substantially. In particular, the relatively smaller gain in providing examples and non-examples suggests that this aspect may require more sustained opportunities for students to identify, distinguish, and construct examples related to mathematical concepts. Mathematical conceptual understanding encompasses not only the ability to apply procedures but also the ability to recognize concept characteristics, distinguish examples from non-examples, and represent concepts appropriately (Abi et al., 2022). Consequently, an overall moderate N-Gain does not imply that every component improved to the same extent.

From a theoretical perspective, the results are consistent with the characteristics of deep learning. Deep learning emphasizes meaningful learning experiences and connections between new knowledge and students' existing understanding (Anwar & Sodik, 2025). Such characteristics are theoretically relevant to mathematical conceptual understanding, which requires students to recognize, represent, connect, and apply concepts (Abi et al., 2022). Previous research has also suggested that deep learning can support meaningful mathematics learning (Maulidya et al., 2025). In the present study, these perspectives provide possible explanations for the observed changes in test performance rather than directly measured evidence of the learning processes involved.

Wordwall may also provide a possible explanation for some of the observed changes. Previous studies have reported the potential of digital learning media to support mathematics learning and learning outcomes (Batubara, 2020; Qomaria et al., 2024). Interactive and game-based activities can present mathematical questions in varied formats and provide opportunities for students to respond to tasks and receive feedback (Putri et al., 2024; Zainuddin, Chu, et al., 2020). These characteristics may be particularly relevant to activities involving the application and representation of mathematical concepts. However, the present study did not directly measure students' engagement, motivation, enthusiasm, or interaction with Wordwall. Therefore, these potential benefits should be regarded as theoretically supported explanations rather than outcomes directly demonstrated by the present data.

No classroom-observation data, interviews, questionnaires, engagement measures, or other process data were collected in this study. Consequently, claims that students participated more actively, became more enthusiastic, explored concepts more deeply, connected prior and new knowledge, or applied concepts in various contexts cannot be directly established from the reported test scores. Such characteristics may be associated theoretically with deep learning and interactive digital media, but they should not be presented as observed outcomes of the present study.

The results showed a statistically significant difference in the students' mathematical conceptual-understanding scores from pretest to posttest, with a moderate average N-Gain of 0.625. The greatest improvement at the indicator level was in the selection and application of procedures or operations (63.31 percentage points), and the least was in providing examples and non-examples (15.73 percentage points). With this pattern, a deeper understanding of the change in students' conceptual-understanding performance is possible than with the overall score alone. The results are generally consistent with previous studies of deep learning and interactive digital learning environments (Maulidya et al., 2025; Qomaria et al., 2024).

However, the results need to be interpreted in light of the limitations of the study design. The study was conducted using a one-group pretest–posttest design without a control group, and only test score data were collected; hence, the observed changes cannot be considered definitive evidence of causal effectiveness or that specific learning processes were responsible for the enhancement. Future studies should use stronger experimental or quasi-experimental designs, larger and more diverse samples, and additional process measures such as classroom observations, questionnaires, interviews, or engagement measures. Such approaches would provide stronger evidence regarding how students experience the learning process and which features of deep learning and Wordwall contribute to changes in different components of mathematical conceptual understanding.

CONCLUSION AND SUGGESTIONS

This study concludes that students' mastery of mathematical concepts improved after learning through Wordwall interactive media integrated with a deep learning approach. The findings indicate that students demonstrated better conceptual understanding after the intervention, with improvements observed across all assessed indicators of mathematical conceptual understanding. The greatest improvement was observed in students' ability to select and perform appropriate operations or procedures, while comparatively smaller improvement was found in their ability to generate examples and non-examples. These findings suggest that the integration of Wordwall interactive media with a deep learning approach can provide meaningful learning experiences and support the development of students' mathematical conceptual understanding. However, the findings should be interpreted with caution because the single-group pretest-posttest design without a comparison group limits the extent to which the observed improvement can be attributed solely to the intervention.

Future research should employ stronger experimental or quasi-experimental designs involving control or comparison groups to provide more robust evidence regarding the effects of deep learning supported by Wordwall interactive media. Studies involving larger and more diverse samples are also recommended to enhance the generalizability of the findings. In addition, future research could incorporate classroom observations, questionnaires, interviews, or measures of student engagement to provide deeper insights into students' learning experiences and the processes underlying changes in mathematical conceptual understanding. Particular attention could also be given to conceptual understanding indicators that show relatively smaller improvements, such as generating examples and non-examples, so that learning activities can be designed to provide more targeted support for different components of mathematical conceptual understanding.

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