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# Students' Mathematical Conceptual Understanding Through a Deep Learning Approach

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**ABSTRACT**

This study investigated whether a pedagogical Deep Learning approach integrating meaningful, mindful, and joyful learning could strengthen eighth-grade students' mathematical conceptual understanding. The study employed a quantitative quasi-experimental method with a randomized control-group-only design. The participants were 62 eighth-grade students at MTsN 6 Lima Puluh Kota during the 2024/2025 academic year. Class VIII.6, consisting of 31 students, was assigned as the experimental group and received instruction through the Deep Learning approach, whereas class VIII.4, also consisting of 31 students, served as the control group and received instruction through the scientific approach. Data were collected using a five-item essay test covering the abilities to restate concepts, provide examples and non-examples, represent concepts in multiple mathematical forms, classify objects according to conceptual characteristics, and apply concepts or procedures in problem-solving. The instrument was reviewed by three mathematics teachers and demonstrated high internal consistency, with a Cronbach's alpha coefficient of 0.84. Descriptive analysis showed that the experimental group achieved a higher mean posttest score than the control group, with scores of 85.60 and 73.80, respectively. The experimental group also outperformed the control group across all conceptual-understanding indicators. The largest difference occurred in applying concepts or procedures to solve problems, with mean scores of 77 and 50, respectively. The independent-samples t-test yielded a value of 3.801, indicating stronger mathematical conceptual understanding among students taught through the Deep Learning approach. These findings suggest that learning experiences emphasizing conceptual connections, reflection, active engagement, and authentic problem-solving can support students in developing deeper and more transferable mathematical understanding. Nevertheless, the findings should be interpreted within the context of a single school, two intact classes, a relatively short intervention, and a posttest-only design.

**ABSTRAK**

Penelitian ini bertujuan menganalisis kemampuan pemahaman konsep matematis siswa kelas VIII setelah mengikuti pembelajaran melalui pendekatan Deep Learning yang mengintegrasikan pembelajaran bermakna, berkesadaran, dan menggembirakan. Penelitian menggunakan pendekatan kuantitatif dengan metode kuasi-eksperimen dan desain randomized control-group-only. Subjek penelitian berjumlah 62 siswa kelas VIII MTsN 6 Lima Puluh Kota pada tahun ajaran 2024/2025. Kelas VIII.6 yang terdiri atas 31 siswa ditetapkan sebagai kelompok eksperimen dan memperoleh pembelajaran melalui pendekatan Deep Learning, sedangkan kelas VIII.4 yang juga terdiri atas 31 siswa menjadi kelompok kontrol dan memperoleh pembelajaran melalui pendekatan saintifik. Data dikumpulkan menggunakan tes uraian sebanyak lima butir yang mengukur kemampuan menyatakan kembali konsep, memberikan contoh dan bukan contoh, merepresentasikan konsep dalam berbagai bentuk matematis, mengklasifikasikan objek berdasarkan karakteristik konsep, serta menerapkan konsep atau prosedur dalam pemecahan masalah. Instrumen telah dinilai oleh tiga guru matematika dan memiliki konsistensi internal yang tinggi dengan koefisien Cronbach's alpha sebesar 0,84. Hasil analisis deskriptif menunjukkan bahwa rata-rata skor posttest kelompok eksperimen mencapai 85,60, sedangkan kelompok kontrol memperoleh rata-rata 73,80. Kelompok eksperimen juga memperoleh skor lebih tinggi pada seluruh indikator pemahaman konsep. Perbedaan terbesar terdapat pada indikator menerapkan konsep atau prosedur dalam pemecahan masalah, dengan skor rata-rata masing-masing sebesar 77 dan 50. Uji independent-samples t-test menghasilkan nilai t sebesar 3,801, yang menunjukkan bahwa siswa yang belajar melalui pendekatan Deep Learning memiliki pemahaman konsep matematis lebih kuat daripada siswa yang belajar melalui pendekatan saintifik. Temuan ini menunjukkan bahwa pembelajaran yang menekankan keterhubungan konsep, refleksi, keterlibatan aktif, dan pemecahan masalah autentik dapat membantu siswa membangun pemahaman matematika yang lebih mendalam dan dapat ditransfer ke berbagai konteks. Namun, hasil penelitian perlu ditafsirkan dengan mempertimbangkan keterbatasan lokasi, jumlah kelas, durasi perlakuan, dan penggunaan desain posttest-only.



## INTRODUCTION

Mathematics plays a crucial role in developing students' foundational understanding and thinking skills. Marliani and Puspitasari (2022) described mathematics as a universal discipline that underpins various fields of knowledge and contributes to the development of individual reasoning. Djafar et al. (2023) further emphasized that, in the context of Industry 4.0, mathematics provides an essential scientific foundation for modern technology and knowledge development. Mathematical competence enables individuals to study the natural world and develop technology that promotes human welfare. Similarly, Khoerunnisa and Maryati (2022) regarded mathematics as an important discipline, often described as the queen of the sciences, that should be studied by every individual.

According to the Ministry of Education, a primary goal of school mathematics is to strengthen students' conceptual understanding so that they can accurately interpret and clearly explain mathematical ideas (Andriani & Septiani, 2020). Mathematics instruction should stimulate innovative thinking and strengthen analytical skills by helping students access prior knowledge and develop a robust understanding of mathematical concepts (Putri & Susanto, 2023). Therefore, mastering mathematical concepts is one of the central goals of mathematics education.

Conceptual understanding is a fundamental prerequisite for learning increasingly complex material and developing higher-order thinking skills (Annisah et al., 2021). According to the 2022 Programme for International Student Assessment (PISA), Indonesia ranked 63rd among 81 participating countries, with an average mathematics score of 366.

Although this ranking was higher than the 72nd-place ranking in 2018, Indonesia's average mathematics score declined from 386 in 2015 to 379 in 2018 and 366 in 2022. These results indicate persistent challenges in students' mathematical conceptual understanding (Achmad et al., 2024). Strengthening conceptual understanding is therefore essential for enabling students to reason logically, analyze problems accurately, and develop solutions based on relevant concepts (Oktavia & Yulia, 2025). When students understand a concept, they can identify the stages of a process and relate that concept to other relevant ideas (Umami et al., 2024).

Teachers need to select learning approaches that reflect students' characteristics, conditions, and backgrounds so that the strategies used can strengthen conceptual understanding and improve learning outcomes. An appropriate approach should stimulate students' interest in mathematics, connect learning to authentic contexts, and help them understand the meaning of the material through deep learning experiences. One approach that may meet these needs is Deep Learning, which emphasizes meaningful learning, active engagement, reflection, and the continuous development of conceptual understanding (Umami et al., 2024).

Nurul Mutmainnah et al. (2021) described Deep Learning as an approach that emphasizes mastery of fundamental concepts and the application of knowledge through reflective and critical thinking. It involves designing a conducive learning environment in which learning is mindful, meaningful, and enjoyable. The approach encourages students to analyze ideas critically, connect new information with prior knowledge, and apply what they learn in authentic situations. Its implementation at the primary and secondary levels is expected to improve student learning outcomes. In mathematics education, Deep Learning focuses on conceptual understanding, reflective ability, and the transfer of knowledge across contexts (I. Dewi et al., 2025). Rather than emphasizing the memorization of formulas, it supports the construction of mathematical meaning and the adaptive application of concepts. These principles may foster critical thinking, self-confidence, and independence in lifelong learning.

The concept of Deep Learning comprises three elements that support a holistic learning experience: meaningful learning, mindful learning, and joyful learning. Meaningful learning emphasizes not only thinking skills but also knowledge that is applicable and relevant to students. It engages students in critical thinking and self-development through interactive activities that help them construct meaning by recognizing patterns and relationships among concepts (Diputera et al., 2024).

Meaningful learning is consistent with the constructivist perspective, which holds that students construct knowledge through authentic experiences by linking new information to what they already know (Vargas-Hernández & Vargas-González, 2022). Accordingly, meaningful learning occurs when new concepts are integrated into existing knowledge structures (Fletcher & Ní Chróinín, 2022).

In addition to meaningful learning, the Deep Learning approach emphasizes mindful learning. Mindful learning activates students' internal resources and potential, improves attention, concentration, planning, and self-regulation, and may reduce emotional reactivity, behavioral difficulties, anxiety, and other barriers to learning (Ročāne & Samuseviča, 2023). It is characterized by active engagement with the learning context, sensitivity to novelty, and the exploration of new information (Wang et al., 2023). Wang et al. (2023) identified five dimensions of mindful learning: (1) flexible learning methods, in which strategies are adapted to different activities; (2) emotion regulation, in which students manage negative emotions when facing obstacles; (3) planning awareness, in which students identify learning goals and strategies; (4) learning engagement, in which students participate actively and deeply; and (5) openness to experience, in which students remain receptive to diverse learning experiences.

In the present study, the teacher guided students through a simple project designed to help them discover mathematical concepts. This activity was intended to stimulate curiosity and active participation while contributing to an enjoyable learning experience. Students' awareness of how they managed their learning, as emphasized in mindful learning, provided a foundation for joyful learning. Joyful learning creates a positive atmosphere that strengthens students' emotional connection to learning and supports deeper understanding (Bhakti et al., 2019). It is designed to help students enjoy learning activities both inside and outside the classroom (Sardin et al., 2022). Yuliana et al. (2025) reported that joyful learning has the potential to foster creativity in mathematics by encouraging students to think openly, participate actively, and engage fully in learning. Games and other interactive activities can further increase students' enthusiasm and motivation.

Based on this framework, the Deep Learning approach, which integrates meaningful, mindful, and joyful learning, offers a viable alternative for mathematics instruction. It involves higher-order thinking and intellectual engagement through questioning, critical thinking, problem-solving, and metacognitive activity, with an emphasis on constructing meaning by recognizing patterns and relationships among concepts (Pambudi et al., 2022). The approach is intended to help students respond to global challenges by strengthening their critical and creative thinking, problem-solving skills, and effective use of technology.

This study involved two groups. The experimental group received instruction using the Deep Learning approach, whereas the control group received instruction using the scientific approach. The study aimed to determine whether the mathematical conceptual understanding of eighth-grade students at MTsN 6 Lima Puluh Kota differed between the two approaches. The findings were expected to inform the development of mathematics learning strategies that are relevant to authentic contexts and support students' mathematical abilities.

## METHOD

This study employed a quantitative approach with a quasi-experimental design. Specifically, a randomized control-group-only design was used to compare an experimental group taught through the Deep Learning approach with a control group taught through the scientific approach. A quasi-experimental design was considered appropriate because individual-level random assignment could not be fully implemented in the existing school setting, while comparisons between groups were still required to examine the effects associated with the instructional treatment (Kim & Steiner, 2016)

The population comprised all eighth-grade students at MTsN 6 Lima Puluh Kota, located at Jalan Raya Bukittinggi-Payakumbuh Km 8, Koto Tangah Batu Hampa, Akabiluru District, Lima Puluh Kota Regency, West Sumatra, during the 2024/2025 academic year. Class-level random sampling was used so that each class had an equal probability of being selected. This technique was considered appropriate because the classes followed the same curriculum, were taught by the same mathematics teacher, were at the same grade level, and had comparable academic characteristics.

Two classes were selected through a random draw: classes VIII.6 and VIII.4, each comprising 31 students. Class VIII.6 was assigned as the experimental group and received instruction using the Deep Learning approach, whereas class VIII.4 was assigned as the control group and received instruction using the scientific approach. Random selection was used to reduce selection bias and increase the likelihood that differences in learning outcomes reflected the instructional treatment rather than pre-existing differences between the classes. MTsN 6 Lima Puluh Kota was selected as the research site because it was accessible for observations, interviews, and data collection.

Students were included if they had attended at least 90% of classes during the preceding month and had no major barriers to participating in mathematics instruction. Students were excluded if health-related or administrative constraints prevented their active participation in the study.

The study included one independent variable and one dependent variable. The independent variable was the Deep Learning approach, which emphasized in-depth analysis, the integration of new information with prior knowledge, and the application of knowledge in authentic situations. The dependent variable was students' mathematical conceptual understanding. The research design is presented in Table 1.

**Table 1.** Research Design

| Group | Treatment | *Posttest* |
|---|---|---|
| *Experimental* | X | T |
| *Control* | Y | T |

Notes:
X: Instruction using the Deep Learning approach
Y: Instruction using the scientific approach
T: Posttest

The research instrument was a five-item essay test designed to measure mathematical conceptual understanding. Each item represented one indicator: restating a concept, providing examples and non-examples, representing concepts in multiple forms, classifying objects according to relevant characteristics, and applying concepts or procedures in problem-solving. Three mathematics teachers reviewed the instrument to evaluate the relevance of the items to the intended indicators, the representativeness of the content, the clarity of the wording, and the appropriateness of the difficulty level. Expert review is essential for ensuring that the content of an instrument adequately represents the construct being measured (Yusoff, 2019).

After content validation, the instrument was pilot-tested with students who had characteristics similar to those of the research participants. Internal consistency was estimated using Cronbach's alpha. The pilot-test analysis produced a reliability coefficient of 0.84, indicating that the items had high internal consistency. Cronbach's alpha was used because it provides information about the extent to which the items in an instrument consistently measure the intended construct, although its interpretation should also consider the number and interrelationships of the items (Tavakol & Dennick, 2011).

The study was conducted in three stages: preparation, implementation, and data analysis. During the preparation stage, the researchers developed the test instrument, conducted expert validation, pilot-tested the instrument, and examined its reliability. The two participating classes were subsequently selected and assigned as the experimental and control groups. During the implementation stage, both groups participated in four instructional sessions. The experimental group received instruction through the Deep Learning approach, integrating meaningful, mindful, and joyful learning, whereas the control group received instruction through the scientific approach. After the instructional treatment, both groups completed the same posttest of mathematical conceptual understanding.

The posttest scores were analyzed using descriptive and inferential statistics. The mean, maximum score, minimum score, standard deviation, and variance were calculated for each group. Before conducting parametric hypothesis testing, the score distributions were examined for normality because the validity of parametric procedures depends partly on whether the normality assumption is reasonably satisfied (Ghasemi & Zahediasl, 2012). The homogeneity of variance between the two groups was also examined before comparing their mean scores.

An independent-samples t-test was subsequently used to determine whether the mean mathematical conceptual-understanding scores of the experimental and control groups differed. This test is appropriate for comparing the means of two independent groups when the relevant parametric assumptions are adequately satisfied (Kim, 2015). The statistical results were interpreted together with the descriptive differences across the five indicators of mathematical conceptual understanding.

## RESULTS AND DISCUSSION

The posttest results for the experimental and control groups are presented in Table 2.

**Table 2.** Descriptive Statistics for Mathematical Conceptual Understanding

| Class | N | Mean | Max | Min | SD |
|---|---|---|---|---|---|
| Experimental | 31 | 85.60 | 100 | 60 | 9.89 |
| Control | 31 | 73.80 | 95 | 45 | 14.13 |

Table 2 presents descriptive statistics for the posttest scores. The experimental group, which was taught using the Deep Learning approach, obtained a higher mean score than the control group, which was taught using the scientific approach.

The mean posttest score was 85.60 in the experimental group and 73.80 in the control group, a difference of 11.80 points. The experimental group also obtained a higher maximum score (100 vs. 95) and a higher minimum score (60 vs. 45). These descriptive results suggest that the Deep Learning approach was associated with stronger mathematical conceptual understanding across the observed score range.

**Table 3.** Mean Scores for Each Indicator of Students' Mathematical Conceptual Understanding

| **No.** | **Indicator of Mathematical Conceptual Understanding** | **Question Number** | Mean Score | |
|---|---|---|---|---|
| | | | **Experimental** | **Control** |
| 1 | Restate a concept | 1 | 98 | 93 |
| 2 | Provide examples and non-examples of a concept | 2 | 84 | 79 |
| 3 | Represent concepts in multiple mathematical forms | 3 | 86 | 73 |
| 4 | Classify objects according to relevant conceptual characteristics | 4 | 83 | 74 |
| 5 | Apply concepts or procedures to solve problems | 5 | 77 | 50 |
| | **Total** | | **428** | **369** |
| | **Mean** | | **85.60** | **73.80** |

Table 3 presents the mean score for each indicator of mathematical conceptual understanding. The experimental group achieved higher scores than the control group on all five indicators, indicating consistently stronger performance among students who received instruction using the Deep Learning approach.

Figure 1 illustrates the differences between the two groups across the five indicators of mathematical conceptual understanding.

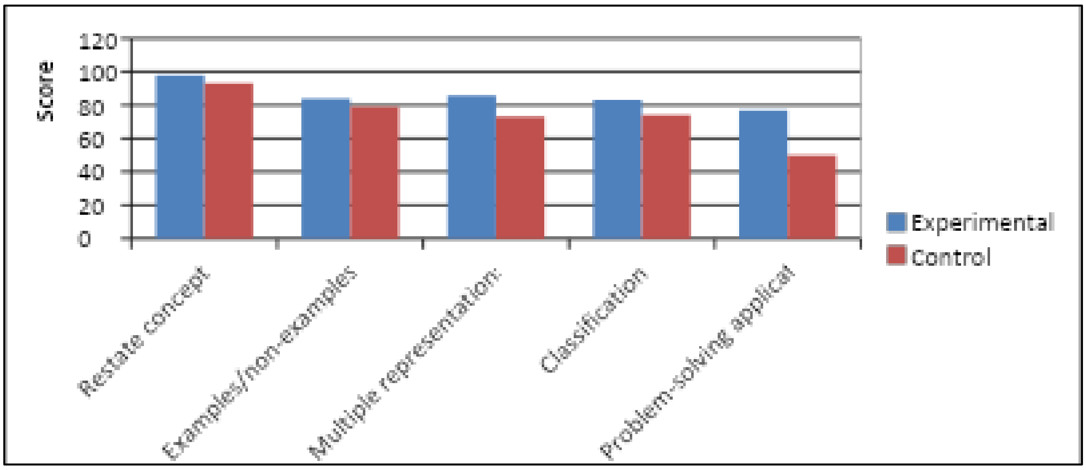


**Figure 1.** Mean Student Scores for Each Indicator of Mathematical Conceptual Understanding

Figure 1 shows that the experimental group achieved a higher overall mean posttest score (85.60) than the control group (73.80). Deep Learning involves higher-order thinking and intellectual development through active cognitive participation, including questioning, critical thinking, problem-solving, and metacognitive activity. These processes support meaning-making through the recognition of patterns and relationships among concepts (Pambudi et al., 2022). By connecting students' prior knowledge with new material, the approach may help them develop coherent cognitive structures and strengthen conceptual understanding.

The score differences across all indicators suggest that the Deep Learning approach contributed more effectively to students' mathematical conceptual understanding than the scientific approach. The highest score in both groups was obtained for the first indicator, restating a concept: 98 in the experimental group and 93 in the control group.

These findings suggest that the Deep Learning approach helped students develop conceptual understanding by emphasizing meaning-making, reflection, and knowledge transfer rather than procedural mastery alone. Students were therefore encouraged not only to recall concepts but also to identify relationships among them and apply them to more complex problems. This interpretation is consistent with I. Dewi et al. (2025), who explained that Deep Learning in mathematics integrates meaningful, mindful, and joyful learning to increase engagement, deepen conceptual understanding, and strengthen knowledge transfer. In the present study, students connected new concepts with prior knowledge, discussed alternative solutions, and reflected on the strategies they used. Such activities may organize mathematical concepts more coherently within students' cognitive structures and make them easier to understand and apply across contexts (Slamet et al., 2025).

Students in the experimental group also performed better in providing examples and non-examples of a concept. As shown in Figure 1, the experimental group obtained a mean score of 84, compared with 79 in the control group. Although this difference was smaller than the difference for applying concepts or procedures, it suggests that Deep Learning supported students' ability to identify the essential attributes of a concept. This ability is an important indicator of conceptual understanding because students must distinguish objects that satisfy a concept from those that do not.

The experimental group's stronger performance suggests that the students developed a deeper conceptual understanding. During instruction using the Deep Learning approach, students did not immediately receive formal definitions. Instead, they observed contextual examples, discussed the characteristics of each object, and formulated the distinguishing features of the concepts. These activities enabled students to construct concepts from their learning experiences rather than merely memorize definitions. This process is consistent with meaningful learning, in which new knowledge is connected to existing cognitive structures. Constructivist research has similarly shown that students often struggle to provide examples of mathematical concepts and that opportunities to construct concepts through exploration can reduce these difficulties (Febindayanti & Sinaga, 2024). Success on this indicator also reflects conceptual thinking, including the ability to identify relationships among definitions, characteristics, and applications. Mathematical conceptual understanding develops through the integration of representation, communication, reasoning, and active participation; therefore, student-centered learning may promote deeper understanding (I. L. K. Dewi et al., 2026). Mindful learning may also have contributed to the experimental group's performance because students were accustomed to explaining why an object was or was not an example of a concept. By contrast, the teacher-centered delivery of concepts in the control group may have limited some students' ability to analyze objects with similar but conceptually distinct characteristics. These students tended to rely on definitions without examining the attributes that distinguished one concept from another, particularly when examples were modified or contextualized.

For the indicator of representing concepts in multiple forms, the experimental group scored 86 and the control group scored 73. This result suggests that Deep Learning supported students' ability to communicate and transform mathematical ideas across verbal, symbolic, visual, graphical, tabular, and model-based representations. Students who received the Deep Learning approach appeared able not only to understand concepts declaratively but also to connect different representations of the same concept. This flexibility is an important indicator of deeper conceptual understanding. Recent research has emphasized that conceptual understanding depends on students' ability to coordinate and transform multiple representations meaningfully, rather than to rely solely on symbolic representation (Asnawati, 2024). The experimental group's stronger representational performance was consistent with the meaning-making emphasis of the Deep Learning approach.

For classifying objects according to relevant characteristics, the experimental group obtained a mean score of 83, compared with 74 in the control group. These results indicate that students taught using the Deep Learning approach were better able to analyze and group objects according to conceptual characteristics. This finding is consistent with Santosa et al. (2025), who argued that Deep Learning promotes conceptual thinking and mathematical reasoning through student-centered instruction. The integration of meaningful, mindful, and joyful learning may have supported this outcome: students connected new concepts with prior knowledge, reflected on their reasoning during classification, and discussed their ideas in an engaging environment. Students in the experimental group were also better able to justify their classifications, whereas students in the control group tended to rely on examples provided by the teacher. This pattern suggests that Deep Learning was more effective than procedure-oriented instruction in developing conceptual understanding. Gianto et al. (2026) similarly reported a positive effect of Deep Learning on students' mathematical conceptual understanding.

The largest difference occurred for applying concepts or procedures to solve problems: the experimental group scored 77, whereas the control group scored 50. This result suggests that the Deep Learning approach substantially strengthened students' ability to connect conceptual knowledge with problem-solving situations. Through critical thinking, reflection, and collaboration, students in the experimental group were better able to select appropriate strategies and apply previously learned concepts to unfamiliar problems rather than only to routine exercises.

This improvement may have resulted from the integration of meaningful, mindful, and joyful learning. Students constructed concepts through contextual problems, reflected on the strategies they used, and discussed alternative solutions. These processes helped them understand why a concept was relevant and how it could be applied accurately. The experimental group therefore appeared better prepared for tasks requiring reasoning, whereas the control group continued to rely more heavily on procedures demonstrated by the teacher. The findings suggest that Deep Learning supported both conceptual mastery and the transfer of concepts across problem-solving contexts. Sitompul et al. (2025) similarly found that a Deep Learning approach strengthened fifth-grade students' understanding of data at SDN 014628.

Overall, the findings indicate that the Deep Learning approach not only strengthened students' conceptual understanding but also supported critical thinking and the transfer of knowledge across learning contexts. Compared with the scientific approach, which in this study placed greater emphasis on systematic procedures, Deep Learning more explicitly encouraged reflection and depth of thought. It activated students' prior knowledge and experiences, connected previously learned material with new concepts, and used simple projects to relate mathematics to authentic situations. These processes helped students construct more coherent cognitive schemas, engage actively in learning, and think critically.

Previous studies have likewise indicated that Deep Learning can improve students' academic achievement. Qoyyimah and Maswar (2025) found that mathemagics, used as an alternative joyful learning method, was more effective than conventional lectures in increasing the higher-order thinking skills of students at SMP Negeri 1 Situbondo. Salong and Ansiska (2025) also reported that an integrative strategy based on mindful, meaningful, and joyful learning improved learning quality.

The findings have important pedagogical implications, particularly for mathematics instruction that aims to move students beyond memorizing formulas and procedures. The consistently higher performance of the experimental group suggests that meaningful connections with prior knowledge, mindful reflection on solution strategies, and joyful participation in contextual activities may jointly support conceptual construction and knowledge transfer. Nevertheless, the results should be interpreted cautiously because the study was conducted in only one school, involved two intact classes, implemented the instructional treatment for four sessions, and used a posttest-only design. The absence of pretest data means that the initial equivalence of the groups was inferred from their educational characteristics rather than directly demonstrated through baseline scores. Accordingly, the findings indicate an observed advantage of the Deep Learning approach within the investigated context but should not be generalized broadly without further evidence. Future studies should employ larger and more diverse samples, use pretest–posttest designs, extend the intervention duration, evaluate implementation fidelity, and report effect sizes to provide a more comprehensive assessment of the pedagogical effectiveness of the Deep Learning approach.

## CONCLUSION

Based on the data analysis and discussion, students who learned through the Deep Learning approach demonstrated stronger mathematical conceptual understanding than those who learned through the scientific approach in eighth grade at MTsN 6 Lima Puluh Kota during the 2024/2025 academic year. The experimental group achieved a mean score of 85.60, whereas the control group achieved a mean score of 73.80. These findings support the use of Deep Learning as an instructional option for strengthening students' mastery and understanding of mathematical concepts while providing an engaging and effective learning experience.

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