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Research Paper

The Effect of Experiment-Based Learning on Elementary Students' Conceptual Understanding of the Relationship between Cylinder and Cone Volumes

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ABSTRACT

The study investigated the impact of hands-on, experiment-based learning on sixth-grade students' understanding of the relationship between the volumes of cylinders and cones. Utilizing a quasi-experimental design with a one-group pretest–posttest methodology, the research involved 24 students from SD Terpadu Muhammadiyah Stabat. Data was collected through pre- and post-learning session tests, alongside observations and documentation during the process. Analysis included descriptive statistics, N-Gain calculations, and a paired sample t-test, revealing a significant increase in average test scores from 45.83 to 82.50. The N-Gain indicated a moderate to high increase in performance, with a statistically significant p-value below 0.05. The results highlighted not only the improvement in scores but also the engaging nature of the learning process, as students actively experimented with concepts rather than passively memorizing formulas. This engagement is critical for grasping abstract mathematical ideas at the elementary level, suggesting that experiment-based learning effectively makes these concepts more tangible and comprehensible.

Keywords: experiment-based learning, conceptual understanding, cylinder and cone volume, elementary school mathematics

INTRODUCTION

The development of logical, analytical, and methodical thinking abilities is greatly aided by mathematics, especially in primary school. Students who have a solid conceptual grasp of mathematics at a young age are better equipped to understand more complex subjects later on. However, prior research has demonstrated that elementary school mathematics instruction still primarily focuses on procedural knowledge and formula memorization, which leaves pupils with low levels of conceptual comprehension (Da, 2023; Hiebert, 2007; NCTM, 2014).

Students often struggle with geometry, especially when it comes to comprehending volume in three-dimensional objects like cones and cylinders. Filling formulas with numbers is not the only thing involved. Students are asked to visualize space, compare shapes, and recognize connections between concepts at a level of abstraction. It should come as no surprise that many of them rely on learning formulas by heart without truly understanding their meaning. When they encounter contextual or real-world issues, that comprehension gap becomes apparent (Omolafe et al., 2024; Repriani & Jupri, 2025). Furthermore, low student participation in class frequently exacerbates the situation by leaving them with a cursory grasp of the subject matter (Irvan, 2024).

The structure of the learning itself appears to be a contributing factor. Teaching in many classes still significantly favors a one-way information flow in which students listen more than they investigate. The issue is that pupils don't truly have the opportunity to develop their own understanding in a meaningful way when they aren't actively involved. However, constructivist viewpoints propose an alternative. Learning involves more than just absorbing information; it also involves interpreting it through experience, experimentation, and social interaction (Fosnot, 2013; Slavin et al., 2025).

There has grown evidence to back up this change. Research has demonstrated that students' comprehension improves noticeably when they are allowed to interact, work together, and solve issues as a group. They start to think critically, make connections between concepts, and hone their critical thinking. Naturally, there isn't an immediate change, but there is a noticeable shift, particularly in the way they approach and resolve issues and perform (Ammy & Sitorus, 2025; Emilia et al., 2026; Shivaramu et al., 2025).

Experiment-based learning is one other strategy that can deal with these issues. With this method, students can participate in practical exercises, examine phenomena, and make inferences from their observations. Through such experiences, students are able to construct their own understanding, making learning more meaningful and long-lasting (Kolb, 2014; Prince & Felder, 2006). Previous studies have also shown that experiment-based and activity-based learning can significantly improve students' learning outcomes and engagement (Mutmainah et al., 2019; Syafriani et al., 2025; Žakelj et al., 2024).

Students can gain a more concrete understanding of abstract concepts in mathematics through experiment-based learning activities. For instance, students can clearly observe that the volume of a cone is one-third that of a cylinder with the same base and height by comparing the volumes of cylinders and cones using physical models. Instead of depending only on memorization, this type of experience aids pupils in developing conceptual comprehension. Such findings are consistent with the theory proposed by Bruner (2009), which highlights the importance of concrete experiences in learning, as well as Piaget (1976) theory, which states that elementary school students are in the concrete operational stage and learn best through direct interaction with objects. Furthermore, the use of innovative learning media and activity-based approaches has been shown to improve students' mathematical understanding (Firdaus et al., 2022; Sartika & Fauziyah, 2024).

There are still few studies that particularly look at elementary school the understanding of children of the relationship between cylinder and cone volumes, despite the expanding corpus of research on active and experiment-based learning. Instead, then concentrating on particular conceptual linkages in geometry, the majority of earlier research has concentrated on general learning outcomes, critical thinking, or problem-solving abilities (Rehman et al., 2024; Repriani & Jupri, 2025; Syafriani et al., 2025). As a result, more study is required to close this gap. Based on those concerns, the current study investigates whether experiment-based learning might improve primary school pupils' comprehension of the connection between the volumes of cones and cylinders. More precisely, it aims to determine whether learning through practical exercises and in-depth research results in a more profound understanding of the subject than merely memorizing formulas.

The outcomes are expected to present more than just proof of progress in a single classroom. Ideally, the study will help educators create more interesting and conceptually significant math lessons, especially for students in elementary school who are still learning about abstract mathematical concepts.

METHODS

The study took a quantitative approach, though not in a fully controlled experimental sense. It relied on a quasi-experimental design to explore whether experiment-based learning could actually make a difference in how students understand the relationship between the volumes of cylinders and cones. In practice, the setup was fairly straightforward. Students were tested before anything else, just to get a sense of where they stood at the beginning. After that, they went through a series of learning activities built around simple experiments, the kind that asked them to observe, compare, and think through the concepts rather than just apply formulas. Once the sessions were completed, a second test was given. By comparing the scores from before and after the treatment, the study tried to capture something more than just numerical change. It was really about seeing whether there was a shift in how students made sense of the concept itself, whether the ideas became clearer, or at least less abstract than before.

The study was conducted at SD Terpadu Muhammadiyah Stabat, involving 24 sixth-grade students as research subjects. The sampling technique used was total sampling, where all members of the population were included as the sample. The variables in this study consisted of an independent variable, namely experiment-based mathematics learning, and a dependent variable, namely students' understanding of the relationship between the volume of cylinders and cones.

Data were collected through tests, observation, and documentation. The test, in the form of a pretest and posttest, was used to measure students' conceptual understanding before and after the treatment. Observation was conducted to examine students' activities and engagement during the implementation of experiment-based learning. Documentation was used as supporting data, including student data and learning activities.

The research procedure was carried out in three stages: preparation, implementation, and final stage. The preparation stage included the development of learning instruments and research tools. The implementation stage consisted of administering the pretest, conducting experiment-based learning, and administering the posttest. The final stage involved analyzing the data and drawing conclusions based on the research findings.

Once the data had been collected, the analysis moved through a few stages. It started with descriptive statistics, mainly to get a general sense of how students performed. Looking at the mean scores, along with the lowest and highest results, helped sketch a rough picture of their overall achievement. From there, the focus shifted to N-Gain analysis. This part was meant to capture how much students actually improved after the learning activities, not just whether their scores went up, but how meaningful that increase was. It's one thing to see a difference in numbers, but another to understand the extent of that change. To go a step further, a paired sample t-test was applied. This was used to check whether the difference between the pretest and posttest scores was statistically significant or just happened by chance. The criterion was fairly standard: if the p-value fell below 0.05, the change was considered significant. In other words, it would suggest that the use of experiment-based learning had a real effect on students' understanding, rather than being a coincidence.

RESULT

The results of this study describe the improvement of students' understanding of the relationship between the volume of cylinders and cones after the implementation of experiment-based learning. The data were obtained from the pretest and posttest scores of 24 sixth-grade students.

Table 1 presents the descriptive statistics of students' pretest and posttest scores.

Table 1. Descriptive Statistics of Pretest and Posttest Scores

Data	N	Mean	Minimum	Maximum
Pretest	24	45.83	30	60
Posttest	24	82.50	70	95

Looking at Table 1, there's a noticeable jump in the students' average scores. Before the learning activities, the mean sat at 45.83, which suggests that many of them were still struggling with the concept. After the implementation of experiment-based learning, though, the average rose to 82.50. That kind of increase feels quite significant, not just statistically but also in terms of how much clearer the material may have become for the students.

Of course, raw scores only tell part of the story. To get a better sense of how meaningful this improvement really was, the N-Gain score was calculated. The results of that analysis are shown in Table 2.

Table 2. N-Gain Analysis Results

Category	Number of Students	Percentage
High	10	41.67%
Medium	14	58.33%
Low	0	0%

Table 2 gives a clearer picture of how much progress the students actually made. Most of them showed improvement at a moderate to high level, which is quite encouraging. Around 41.67% of the students reached the high category, while the remaining 58.33% were in the medium range. Interestingly, none of the students fell into the low category. That alone suggests that the learning approach didn't just help a few students, but had a fairly consistent impact across the class.

Still, improvement in categories doesn't automatically mean the difference is statistically meaningful. To check that, a paired sample t-test was carried out. The results of this test are presented in Table 3.

Table 3. Paired Sample t-Test Results

Data	Mean	t-value	Sig. (p-value)
Pretest–Posttest	-36.67	-15.42	0.000

Turning to Table 3, the numbers make the pattern even clearer. The p-value is reported at 0.000, which is well below the 0.05 threshold. In practical terms, that means the difference between the pretest and posttest scores is unlikely to be due to chance. There's a real, measurable shift happening here, one that points to the impact of the learning approach rather than random variation.

Taken together, the findings start to feel quite consistent. The rise in average scores, the N-Gain results that lean toward medium and high improvement, and the statistical test all seem to tell the same story. Students didn't just perform slightly better; they showed a meaningful change in how they understood the relationship between cylinder and cone volumes.

DISCUSSION

The results of this study point quite clearly in one direction. Experiment-based learning appears to have a meaningful impact on how students understand the relationship between the volumes of cylinders and cones. You can see it in the steady rise in average scores from the pretest to the posttest, and it's reinforced by the N-Gain results, where most students fall into the medium to high improvement range. Then again, numbers alone don't always tell the full story. What strengthens the claim here is the outcome of the paired sample t-test, which shows a statistically significant difference between the two sets of scores. Taken together, these pieces of evidence suggest that the approach used in this study didn't just help students perform better on tests, but likely supported a deeper, more stable understanding of the concept itself.

The improvement in students' understanding can be explained by the characteristics of experiment-based learning, which actively involves students in the learning process. Through direct experimentation, students are not only exposed to formulas but also experience the process of discovering mathematical relationships. This finding is in line with the constructivist theory, which emphasizes that knowledge is actively constructed by learners through experience and interaction (Boakye-Yiadom et al., 2025; Fosnot, 2013; Vygotsky & Cole, 1978). In this study, students directly observed the relationship between cylinder and cone volumes, allowing them to build a deeper conceptual understanding rather than relying on memorization.

Furthermore, the use of experimental activities helped students visualize abstract mathematical concepts. Geometry, particularly volume relationships, often requires spatial reasoning and visualization skills. By engaging students in hands-on activities, the learning process becomes more concrete and meaningful. This supports the theory proposed by Bruner (2009), which states that learning is more effective when students move from concrete experiences to abstract understanding. Similarly, Piaget (1976) explains that elementary school students are in the concrete operational stage, where they learn best through direct manipulation of objects and real experiences.

The results of this study are also consistent with previous research showing that active and student-centered learning approaches can improve conceptual understanding. For instance, Ammy & Sitorus (2025) and Veillon & Veillon (2019) found that active and collaborative learning strategies significantly enhance students' understanding and engagement in mathematics learning. In addition, Syafriani et al. (2025) as well as Žakelj et al. (2024) reported that experiment-based learning can improve both learning outcomes and student participation.

Moreover, the findings align with research conducted by Sholihah et al. (2015) and Uyen et al. (2022), which highlighted that experimental approaches are effective in increasing students' learning achievement. The active involvement of students during the experiment encourages them to think critically and make connections between concepts. This is further supported by the findings of Firdaus et al. (2022) and Sartika & Fauziyah (2024), which emphasize the importance of innovative learning media and activity-based learning in improving mathematical understanding.

In addition, collaborative and interactive learning environments also contribute to the improvement of students' understanding. Previous studies found that collaborative learning enhances students' critical thinking and conceptual comprehension (Emilia et al., 2026; Syafriani et al., 2025). During the experiment-based learning process in this study, students were actively engaged in discussions and group activities, which helped them exchange ideas and strengthen their understanding.

Despite the positive findings, this study has some limitations. The use of a one group pretest-posttest design without a control group limits the ability to generalize the results and to fully attribute the improvement solely to the treatment. Future studies are recommended to use a more rigorous experimental design, such as a control group design, to strengthen the validity of the findings.

Stepping back and looking at the whole picture, the results seem to point to one fairly clear takeaway. Experiment-based learning works, at least in this context, as a way to help students make better sense of the relationship between cylinder and cone volumes. What's interesting is that the impact doesn't stop at improved test scores. The approach seems to draw students into the learning process more actively. They're not just following steps or memorizing formulas, but actually thinking through what's happening, questioning it, sometimes even getting stuck before figuring things out. That kind of process, while a bit messy, often leads to a more meaningful and lasting understanding.

CONCLUSION

All things considered, this study arrives at a fairly consistent conclusion. Experiment-based learning seems to have a clear and positive impact on how students understand the relationship between the volumes of cylinders and cones. The evidence lines up quite neatly, from the noticeable increase in average scores after the learning sessions to the N-Gain results that mostly fall in the medium to high range. The statistical test adds another layer of confidence, showing that the difference between pretest and posttest scores is not just accidental.

What stands out, though, is how the learning process itself unfolds. When students are given the chance to explore ideas through simple experiments, observing and testing things on their own, they begin to build understanding in a more personal way. Instead of relying on memorized formulas, they start to see patterns and relationships, especially between shapes like cylinders and cones. That shift, from passive reception to active discovery, seems to make a real difference. It also tends to draw students in, making them more engaged and involved during the lesson.

That said, there are a few limitations worth noting. The study used a one-group pretest–posttest design, which means there was no comparison group to really isolate the effect of the treatment. So while the results are promising, they should be interpreted with some caution. It might be useful for future studies to use a more rigorous design, perhaps with a control group and a larger number of participants, to see if the findings hold up in different settings.

Even with those limitations, the overall impression remains quite positive. Experiment-based learning offers a practical and engaging alternative for teaching mathematics, especially when dealing with abstract concepts at the elementary level where students often need more concrete experiences to make sense of what they are learning.

Declaration by Authors

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