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Realist hands-on learning approach and its contributions to learners' conceptual understanding and problem-solving skills on solid geometry

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ABSTRACT

This study aimed to examine the application of a realist hands-on learning approach and its contributions to optimizing the solid geometry conceptual understanding and problem-solving skills of students. It employed a non-equivalent pre-/post-test quasi-experimental research design. The results showed that there was a statistically significant mean difference between the intervention group and the comparison group, with an effect size of d=.825 for the students' solid geometry conceptual understanding and d=.930 for the students' problem-solving skills. Furthermore, a strong correlation was observed between students' conceptual understanding and problem-solving skills in solid geometry, with an r^2 of .6413. These indicate that the use of a realist hands-on approach positively contributes to optimizing learners' conceptual understanding and problem-solving skills. It also provides contextually relevant learning opportunities; therefore, it is recommended that teachers and concerned bodies employ a realist hands-on approach to make solid geometry learning concrete and practical.

Keywords: Realist-hands-on approach, solid geometry, problem-solving skills, conceptual understanding

INTRODUCTION

Geometry plays a crucial role in various fields including organic chemistry, and biology, computer animation, virtual reality, in the area of medical imaging, robotics, geometric modelling (including design, modification and the manufacture of cars and airplanes, in the construction of buildings, bridges, dams and others (Glaeser, 2020). The author stated that it is also found in the structure of solar systems, plants, animals, rocks, and crystals.

We need to learn geometry not only for the significance it holds in several fields, but also because our physical realm is filled with geometrical forms and things (Jablonski & Ludwig, 2023). Although geometry plays an indispensable role in different sectors, studies have revealed that it is seen as a difficult area in mathematics, most probably as a result of students' poor geometric reasoning skills, teaching approach, poor background knowledge, lack of visualizing abilities, and poor student knowledge of proofs (Alghadari & Herman, 2018). But again, a lack of relating geometry with daily activities and the support of students to engage with locally available geometric objects and build hands-on capabilities could be important factors. As a result of these factors, a large number of students have failed to develop an understanding of geometry concepts, reasoning, and problem-solving skills that cause poor achievement. Poor understanding of learning geometry, which can lead to poor performance in geometry, often causes discouragement among students (Purnomo & Machromah, 2018). The Ethiopian national learning assessment conducted every four years in series during 2000, 2004, 2007, 2011, 2015, and 2020 has shown that students' mathematics achievement of grade eight averages was 38%, 41%, 34%, 26%, and 36%, respectively (Tiruneh et al., 2021) and 31% (National Educational Assessment and Examinations Agency [NEAEA], 2020). These show that in all six rounds, pupils' mathematical achievement fell below the 50% cut point imposed by the ministry of education, and the assessment examinations include elements of geometry, albeit an express score in geometry is not published. Geometry is one of the strands in mathematics that students struggle to learn, and from geometry, the solid geometry part, which is three-dimensional (3D) but taught in a two-dimensional (2D) setting, is the most difficult for them to understand and solve problems under these topics (Ng et al., 2020; Watan & Sugiman, 2018). It is one of the most challenging areas of mathematics education, and it has been reported that the performance of the students on solid geometry was very poor (Zhang, 2021).

Rahimi et al. (2019) discussed that solid geometry is a 3D geometry that is difficult to teach on board and paper alone. Students cannot understand the concepts and develop problem-solving skills of solid geometry when they are taught through lectures and demonstrations (Alghadari et al., 2020; Pramuditya et al., 2019). Juman et al. (2020) also disclosed that some of the persistent causes for students to face challenges in learning geometry may be due to the inappropriateness of instructional approaches. Hence, as part of strategies to mitigate the problems, mathematics teachers may need to focus on instruction that promotes students' better learning and achievement, among other things, by relating the teaching to real-life situations and making them hands-on. Mazana et al. (2020) state that the instructional approach teachers adopt could make learners develop a negative or positive interest in learning tasks. Therefore, the need to explore appropriate instructional approaches that could enhance students' learning and achievement in geometry is a critical issue for mathematics educators. However, there is the belief that it is possible to increase students' learning and achievement by engaging them in realistic and practical mathematics learning rather than focusing solely on being an expert on memorized knowledge (Loc et al., 2022). Generally, students' involvement in mathematics using real objects from their contexts and a hands-on learning approach via mathematical manipulatives and models can excel their mathematics learning and achievement (Jones & Tiller, 2017). It is also noted that the use of hands-on learning-based instructional practice helps students build their mathematical conceptual understanding and problem-solving skills (Dahlan & Wibisono, 2021). The hands-on learning approach via mathematical manipulatives and models can help teachers address mathematical practice, particularly by making the learning concrete and developing a sense of problem-solving skills. Studies have evaluated the effectiveness of such an approach as a tool in mathematics instruction (Kukey et al., 2019).

Nevertheless, some researchers have reported that the advantages of instruction using manipulatives and models are inconsistent. For example, Peltier et al. (2020) indicated that a recent meta-analysis of 55 studies that compared instruction with or without manipulatives suggests that manipulatives can benefit learning but only under certain conditions. The conditions could vary, and the types of hands-on-based learning are diverse. From one perspective, the questions 'What would happen if one used realistic and context-bound hands-on learning?' and What would the case be in the context of Ethiopia and with particular reference to learners' conceptual understanding and problem-solving skills of solid geometry?' are worth studying. Exploring the extent to which the use of a realistic-based hands-on learning approach optimizes the learners' conceptual understanding and problem-solving skills and the association between these two is also of interest.

Statement of the Problem

Employing an appropriate instructional approach is vital for better understanding. It is believed that the selection and use of an appropriate instructional approach influences learning, and students' hands-on engagement improves understanding and reasoning, especially when it is associated with real context. Solid geometry, as 3D, is better understood when presented visually with the use of local objects and conducted practically than with imagery and drawings. From the supervision and classroom observation experiences, the researchers noted that teachers used largely lecture methods in the mathematics classroom, including the teaching of solid geometry, and they used 2D blackboard to teach solid geometry, which demanded students relate a three-dimension with a two-dimension. Students were challenged to understand the concept of 3D figures and were staggering to solve problems related to solid figures. The maximum effort teachers took was simply to draw a 3D figure on the chalkboard, which is a 2D figure but represents 3D one. This made it challenging for the students to visualize the solid figures and develop an understanding.

In solid geometry learning, which is 3D, attempting to deliver instruction on the board has double challenges for the learners: understanding the concept as 3D and viewing it transformed into a 2D plane figure. In addition, when teachers use the lecture method, the problem exacerbates and causes difficulty understanding solid geometry. Although instructional strategies like teacher exposition have a place in mathematics education, they are more likely to induce concept memorization than meaning-making (Senel Tekin et al., 2020). However, it has been strongly suggested that it is possible to make the teaching-learning process of solid geometry meaningful and practical by using different models, one of which is the use of manipulatives (Nduka & Ajoke, 2016), and that teaching mathematics with models as instructional materials improves students' performance (Istiandaru et al., 2017).

Students' poor understanding and performance in examinations and the influence of teaching and learning on students' performance provided a basis to look at the use of a real context-based hands-on instructional approach and its effect on learners' conceptual understanding and problem-solving skills in solid geometry. While the positive contributions of the use of hands-on instructional approaches have been affirmed as improving learners' performance and learning outcomes, the fact that some studies reported inconsistent results necessitated the need to study them, particularly in relation to conceptual understanding and problem-solving skills, which are key in mathematics learning. Therefore, this study aimed at examining the extent to which a realist hands-on learning approach via manipulatives and models optimizes the conceptual understanding and problem-solving skills of students in learning solid geometry.

Purpose of the Study

This study aimed to determine the extent to which the realist hands-on learning approach optimizes grade seven students' conceptual understanding and problem-solving skills in learning solid geometry.

Research Hypotheses

The following are the null hypotheses that this research seeks to examine:

1. There is no statistically significant mean difference in conceptual understanding and problem-solving skills between the intervention and comparison groups.
2. There is no statistically significant relationship between students' solid geometry conceptual understanding and their problem-solving skills.
3. Does the use of realist hands-on learning influence students' conceptual understanding and problem-solving skills?

Theoretical Framework

Piaget placed a strong focus on teaching from the concrete to the abstract to help students make sense of their mathematical learning. Like Piaget, Bruner proposed the inactive, iconic, and symbolic stages as the three stages of a student's mathematical learning, where the inactive stage allows students to interact with tangible objects (manipulatives). Dewey asserted that mathematical learning loses all significance in the absence of actual experience and that the teaching strategy of hands-on learning with mathematical manipulatives aids in maximizing mathematical learning (Rosli et al., 2015). This is because mathematics is abstract by nature, necessitating the involvement of students (especially young ones), who may then develop meaningful mathematical concepts with the use of a hands-on learning strategy using mathematical manipulatives and models (Vanshina et al., 2021). Since it takes a lot of practice for young learners to develop the mental capacity needed to understand these abstract mathematical concepts, meaningful mathematical learning will always take place whenever learners, especially young ones, are familiar with concrete materials (Jones & Tiller, 2017).

The constructivism learning theory supports active learning through student interaction and participation in the classroom by encouraging students to build meaningful mathematical knowledge and develop critical thinking in cognitive, cultural, emotional, and social dimensions (Zajda, 2021). In this theory of learning, learners are the central agents of their own learning since they themselves construct mathematical knowledge, and therefore, mathematical knowledge is not out there, external to the child, waiting to be discovered (Brown, 2016; Zajda, 2021).

A hands-on learning approach aided by mathematical manipulatives and models, which relies on the constructivist philosophy of education, is learning by doing. Contextualization and situating learning also provide meaningful learning as they promote the application of students' prior experience and daily life experiences to boost understanding of abstract ideas. These both engage students in an activity and hence maximize learners' motivation, engagement, and overall learning success (Kwon & Capraro, 2018).

Some studies indicate that mathematical manipulatives and models help students understand abstract mathematical concepts by making them more concrete (Hidayah et al., 2018; Liggett, 2017). Other researchers have also suggested that mathematical manipulatives enhance students' mathematical conceptual understanding and problem-solving skills (Hidayah et al., 2018). Therefore, in this study, it is believed that better conceptual understanding and problem-solving skills in solid geometry could be developed whenever students are highly involved in constructing their knowledge with the help of manipulatives and realist hands-on activities using locally available concrete materials.

METHODS

Study Context

The study was carried out in two primary schools in the North Shoa Zone, one of the 21 zones of the Oromia Regional State. The study area is located to Northwest at Fitche Town, 112 km. away from Addis Ababa, the Capital City of Ethiopia. In the town, there are four full primary schools that offer education from grade 1 through grade 8. Afan Oromo is the medium of instruction for primary education in the region. However, the Amharic language, as the federal working language, is also used as an alternative for school instruction. Since Fitche is a small zonal town, both rural and urban students are admitted to these schools. Even though most contents of mathematics, including geometry, are perceived as difficult and abstract, the students are from a community in which many geometrical concepts are applied in several agricultural, home, and social activities. Geometric shapes and solid objects are among the contents offered in primary mathematics education in Ethiopia. However, the contents of surface area, total surface area, and volume of cubes, prisms, and cylinders are offered in upper primary education, at grade 7 and grade 8. According to the national syllabus, the students are expected to develop different ways of thinking and solving problems and to have a deeper and broader understanding and skill in computation and application upon completing their primary education.

Research Design

This study used a quantitative research approach with a non-equivalent pre-post quasi-experimental research design. Two of the four elementary schools were chosen and assigned to intervention and comparison groups at random.

Intervention

The two groups were taught the surface area and volume of 3D objects with different approaches. The treatment group was taught with the help of a realist hands-on learning approach, and the comparison group was taught using the conventional method without a planned realist hands-on learning approach. For the implementation of the realist hands-on learning approach, materials such as 3D cartons, scissors, cutters, hard papers, pencils, scotch tape, plaster, rulers, pins, ropes, and unit cubes were distributed among the groups consisting of six to seven students within the treatment group. Models were provided for observation and demonstration. After distributing those materials, groups started their activity by identifying the meaning of the faces, edges, and vertices of 3D cartons, and then identifying the number of faces, edges, and vertices. Next, they attempted to change 3D objects to 2D objects (for example, nets). The ultimate goal for identifying the number of faces and changing these from 3D to 2D (net formation) was to compute the surface area of a given 3D object. Since they are familiar with finding the area of triangles, rectangles, parallelograms, and circles from their prior grades, they can easily find the area of the net they obtained. The groups made different 2D objects of different sizes, and then they tried to find the total area of the nets they formed. Additional activities had been provided for the students so as to develop the concept of the surface area of 3D objects and solve problems with surface area. **Figure 1** shows the nets of 3D objects

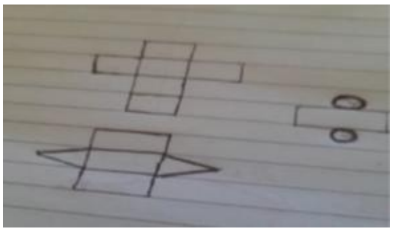

Figure 1. Nets of 3D objects (Source: Field study)

After forming different nets, the groups bent the nets to form 3D objects. While doing these, they have to identify the bases of 3D objects and their lateral faces with their meanings so as to differentiate the total surface area from the lateral surface area of 3D objects. Through the process, they also developed the concept of volume and tried to relate the volume concept to the base area and height of the given 3D objects with the close assistance of their teacher. As an example, they were provided with tins of cylinders. They formed the nets of the cylinder they were provided to help them see the resulted rectangular and circular regions. They also developed the relationship between the radii of the circles and the horizontal and vertical lengths of the rectangle. The circumference of the circles $b=2\pi r$ implies that $r=b/2\pi$, where $\pi\approx3.14$. **Figure 2** shows the cylinder and its net.

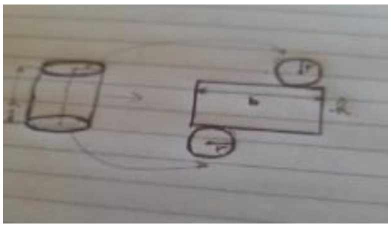

Figure 2. Cylinder & its net (Source: Field study)

Based on these, the students tried to measure the circumferences of water pipes of different sizes in school by using ropes, trying to find the radius of the pipe, and then measuring the length of the rope to understand their relationship. They were guided to determine the lateral surface and total surface areas. They were further engaged in similar activities to solve problems regarding the surface area and volume of a cylinder. They also used the unit of cubes by putting one on top of the other to understand the concept of volume in 3D objects. Different locally available materials were also used to engage them with hands-on activities and find areas and volumes. These topics were chosen because they were the ones indicated in the syllabus of the school curriculum.

Participants of the Study

Participants in the study were grade 7 students at Bowa Primary School and Abiyot Fire Primary School located in the town. Bowa Primary School had 32 7^{th} grade students in the 2020-21 academic year, and this was assigned to be an intervention group. Abiyot Fire Primary School, which had 29 students in the same academic year, was assigned as a comparison group. Student participants were between 12 and 16 years of age, and only 58 students (30 from the intervention group and 28 from the comparison group) sat for the post-test.

Instruments & Procedures of Data Collection

Pre- and post-testing were used to obtain the data. Pre- and post-tests were designed with multiple-choice and workout items. Multiple-choice items were used for measuring conceptual understanding, whereas the workout items were utilized to measure problem-solving skills. A rubric was developed to score the problem-solving skills. The researchers prepared both test items using a table of specifications. The pre-test items were administered to both groups in order to identify their initial level of understanding and problem-solving skills. After the pre-test, the realistic hands-on learning approach was used for the intervention group for four weeks, while the accustomed instructional approach was used for the comparison group. After the intervention, the post-test was administered to both groups to see the differences between them.

Reliability & Validity

As reliability refers to internal consistency within the instrument, correlation between the items was calculated to check if the items measure the same construct. To this effect, Cronbach's alpha was computed to measure reliability for the test on students' conceptual understanding, and an inter-rater reliability test was computed to measure reliability of the items on problem-solving. The tests were administered to 30 grade 8 students of Abiyot Fire Primary School, and the reliability coefficients were 0.82 and 0.75 for conceptual understanding and problem-solving skills tests, respectively, each of which is within the acceptable range of reliability. Validity is the extent of a measuring instrument's determination and precision in completing its measuring function (Sudaryono et al., 2019), competency statements specified in the syllabi for the grade level were used for item construction, and solid geometry tests were prepared based on a table of specifications drawn from the syllabus. The tests were given to two mathematics teachers for review to ensure face and content validity. Based on their suggestions, the researchers made some amendments to the tests. The prepared tests were piloted at Abiyot Fire Primary School on grade 8 students, and the results were analyzed in relation to their aggregate scores in grade 7 to ensure construct validity.

Data Analysis

The data analysis was done in line with the research hypotheses. To identify whether there was a statistically significant difference between the comparison and treatment groups, an independent sample t-test was computed. Furthermore, to check whether there was a statistically significant correlation between students' conceptual understanding and their problem-solving skills, the Pearson product moment correlation was used. To uncover the extent of the effect of using a realistic hands-on approach, mean gain differences were compared. Before applying these two statistical tests, different assumptions for the tests were checked, and all the assumptions were not markedly violated.

RESULTS & DISCUSSION

Results

This section presents results and discussion for each of hypotheses stated. Before intervention, a pre-test was administered to compare the level of the students' conceptual understanding and problem-solving skills in both groups. The result of the pre-test presented in **Table 1** shows the independent sample t-test results of students on conceptual understanding and problem-solving skills before the start of the intervention. The two groups had no statistically significant mean difference (t[59]=-5.68, p=0.124 for conceptual understanding and t[59]=3.45, p=0.302 for problem-solving skills). This indicates that the students exposed to the hands-on learning approach and the traditional approach were equivalent before the intervention started.

Table 1. Comparison of intervention & comparison groups on students' pre-test conceptual understanding & solid geometry problem-solving skills

Variable	Group	n	Mean	Standard deviation	t	df	sig
Conceptual understanding	Comparison group	29	4.48	2.32	-5.68	59	.124
	Intervention group	32	4.52	2.00			
Problem-solving skills	Comparison group	29	2.37	1.54	3.45	59	.302
	Intervention group	32	2.35	2.10			

Realistic hands-on learning approach & conceptual understanding & problem-solving skills

After conducting the intervention, an instructional approach using hands-on learning was used to compare the conceptual understanding and problem-solving skills of the intervention and the comparison. The result presented in **Table 2** shows that the intervention group outperformed the comparison group on solid geometry conceptual understanding (t[56]=-2.824, p=0.006<.05) and problem-solving skills (t[56]=-3.438, p=0.001<.05). Inspection of the two group means indicates that the average solid geometry conceptual understanding score for the comparison group (5.93) is significantly lower than the score (7.15) for the intervention group. The mean difference between groups is (1.22) with an effect size d (Cohen's d) of 0.825, which, based on the suggestions of Cohen (1988), is considered to be large. A similar result for problem-solving skills was also observed, where the average solid geometry problem-solving skills score for the comparison group (3.62) is significantly lower than the score (5.02) for the intervention group, with a mean difference of 1.40 and an effect size d (Cohen's d) of 0.93, which, based on the suggestions of Cohen (1988), is considered to be large. Both results indicate that the use of a realist hands-on learning approach had a positive effect on students' solid geometry conceptual understanding and problem-solving skills in a meaningful way.

Table 2. Comparison of intervention & comparison groups on students' post-test conceptual understanding & solid geometry problem-solving skills

Variable	Group	n	Mean	Standard deviation	t	df	sig
Conceptual understanding	Comparison group	29	5.93	1.56	-2.82	56	.006
	Intervention group	32	7.15	2.19			
Problem-solving skills	Comparison group	29	3.62	1.08	-3.44	56	.001
	Intervention group	32	5.02	1.84			

Association between students' conceptual understanding & problem-solving skills

An attempt was made to check if an increase in conceptual understanding is associated with an increase in problem-solving skills and vice versa as a consequence of the use of a realist hands-on skill learning approach in the intervention group. **Table 3** indicates the Pearson product-moment correlation coefficient r(30)=.801, p=.000 for the intervention group, and r(28)=.304, p=.109 for the comparison group. The correlation for the intervention group showed a statistically significant difference, but not for the comparison group. The direction of correlation for the intervention group is positive, which means students who have a higher level of understanding tend to have higher problem-solving skills and vice versa. The r-squared value of 0.6413 indicates that approximately 64% of the variance in problem-solving skills can be explained from their conceptual understanding.

Table 3. Correlations between students' post-test conceptual understanding & problem-solving skills of intervention group (n=30) & comparison group (n=28) (**p=.000< 0.01)

Problem-solving skills			
Variables	**Intervention group**	**r^2**	**Comparison group**
Conceptual understanding	.801**	0.6416	.304

Discussions

The findings in **Table 2** revealed that there is a significant difference in students' solid geometry conceptual understanding and problem-solving skills in favor of the group taught with the help of a realist hands-on learning approach, with larger effect sizes (Cohen's d) of 0.825 for understanding and 0.93 for problem-solving. These indicate that the intervention brought meaningful positive change to students' conceptual understanding of solid geometry and problem-solving skills. The intervention with realist hands-on activities has improved the conceptual understanding of the students and their problem-solving skills. These findings are consistent with the findings of Riastuti et al. (2017) and Ukobizaba et al. (2021), whose findings revealed that students taught with the help of a hands-on learning approach outperform their counterparts taught using the traditional way in learning solid geometry. The finding also coincides with Verner et al. (2019), who found that students taught with the help of a hands-on learning approach understood solid geometric concepts better than those taught with a traditional approach. From these, we can conjecture that students need active participation as well as practical engagement with activities supported by hands-on skills in general and realist hands-on skills in particular using geometrical models and manipulatives when learning solid geometry to make the learning meaningful and entertaining.

Likewise, the realist hands-on skills approach to learning also helped students to easily view 3D objects and capture 2D figures of these objects (nets of solid figures) and vice versa. The approach supports students' ability to easily identify surface area from total surface area and dimensional view against the surface in the coordinate plane. It further helps them to solve problems regarding the surface area and determine dimensions, and it provides an opportunity to prepare 3D models from locally available materials, which further helps them to identify the length, width, and height of a 3D figure. The approach also provides the students with an opportunity to relate their learning to their daily life activities and to understand their surroundings. Therefore, a realist hands-on learning approach is useful and important to improve students conceptual understanding of solid geometry and problem-solving skills. For example, one of 3D figures they prepared was a number of cubes of dimensions 1cm x 1cm x 1cm. With the help of these cubes, they filled the boxes of a rectangular prism with different dimensions, which helped them solve problems of volume for 3D objects with different dimensions. They prepared cylindrical models and the corresponding nets from locally available materials with a height of 1cm. This helped them to differentiate the radius and height of the cylindrical models, which in turn helped them to differentiate the concepts of surface area and total surface area and solve problems of surface area, total surface area, and volume of cylindrical figures. It was identified that a realist hands-on learning approach helps students in the intervention group solve problems of surface area, total surface area, and volume of 3D figures with better standing than the learning in the comparison group. In support of this, the finding of Ummah et al. (2019) revealed that learning via a hands-on learning approach enables students to boost their skills in solving solid geometry problems and understand the contents in a better way. The findings also agree with earlier studies by Chusinkunawut et al. (2018) and Hidayah et al. (2018), who revealed that learning solid geometry by using 3D models and their nets (manipulatives) in a collaborative manner assisted students to comprehend the concepts of the solid figures easily.

The approach empowers students to identify and define a problem, create strategies to solve it, and support their reasoning with scientific methods at each step while solving a given solid geometry problem. The findings of our study also disclosed that, within the intervention group, there was an improvement with a larger effect size and a strong correlation between students' conceptual understanding and problem-solving skills.

The Pearson product moment correlation coefficient of r=0.801 indicates that students with better conceptual understanding were found to have better skills in solving solid geometry problems and vice versa. In line with this, the findings of Alghadari and Herman (2019), Đokić et al. (2022), Hidayah et al. (2018), and Ukobizaba et al. (2021) indicated that a student who has no access to using 3D models (manipulatives) in a solid geometry classroom has demonstrated limited knowledge about solid geometry and problem-solving skills. Students who were taught using the traditional approach possessed lower conceptual knowledge in solid geometry, and hence not only could they face challenges in solving solid geometric problems but also showed poor ability to solve geometry problems as compared against the intervention group, where within the intervention group, the correlation between students' conceptual understanding and their problem-solving skills was found to be strong. This association can be attributed to the intervention and shows that teaching the learning process of solid geometry with the help of different locally available 3D models and their nets enhances the development of students' conceptual understanding and problem-solving skills.

The finding of this study supports earlier research findings of Đokić et al. (2022), Jones and Tzekaki (2016), Kwon and Capraro (2018), and Ummah et al. (2019), who showed that students' conceptual knowledge about geometry helps them to understand and compare the knowledge in their environment, apply it in their real lives, and use it to solve problems about solid geometry. Students' problem-solving skills in solid geometry were found to be associated with knowledge about concepts of solid geometry, and learning approaches with the help of realist hands-on skills could help achieve the benefits of attaining better conceptual understanding and problem-solving skills. Applicable and strong knowledge is gained by making the teaching and learning of solid geometry practical, contextually relevant, and engaging students with real-world hands-on activities. By implementing such teaching-learning approaches, students were found to participate actively, do things collaboratively, manipulate solution methods by using models, and connect the learning with their real lives (Nurudin et al., 2019). Therefore, the findings of this study imply that a realist hands-on learning approach enhances students' solid geometry conceptual understanding and improves their problem-solving skills for solid geometry problems. Linking learning with locally available models and manipulatives and engaging students in hands-on activities is beneficial to building the benefits of improved conceptual understanding and problem-solving skills.

CONCLUSIONS & IMPLICATIONS

In this study, we saw a statistically significant improvement and difference in both conceptual understanding and problem-solving skills among the students who were taught with the help of a realist hands-on learning approach. Realistic, hands-on learning approach provides students with an opportunity to learn solid geometry practically. Accordingly, schoolteachers need to plan and employ hands-on approaches with the help of manipulatives and models in the teaching and learning of solid geometry to help their students better understand the concepts and develop problem-solving skills. Such an approach also gives an opportunity for the teachers themselves to develop awareness, interest, and skill in using locally available materials from their surroundings (it is better to make a clear relationship between the development of an understanding and problem-solving skills through the utilization of locally available materials and the implementation of a hands-on learning approach) to teach mathematical concepts such as solid geometry. As Ethiopia is undertaking curriculum reform, placing the role of realistic hands-on approaches by using manipulatives and models would contribute to the reform process, improve learning outcomes, and improve the quality of education. These can also be incorporated into the continuous professional development packages for teachers.

Limitations of the Study

The study was not conducted without limitations. Some of the limitations include the following: Considering more intervention groups as replication could have added value to the results of the study. But the fact that there was only one intervention group might limit the observed results. The fact that the sample size is small might affect the statistics observed and their associated comparisons. The study also did not consider all locally available materials to be realistic hands-on learning, but only a sample. The use of diverse materials could have led to other types of findings.

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Ethical statement: The authors stated tht the study was part of a graduate study where during the development of the proposal, there was no institutional review board in the University. In stead proposals had to pass a rigorous process of being examined by internal and external reviewers and examiners, later reviewed and approved by graduate council, and finally checked by department academic council. The authors further stated that the study has passed through all these processes to compensate for the institutional review board approval. All protocols of ethics in research that included autonomy, beneficence and non-maleficiene, and confidentiality were upheld. The right to withdraw at any time was also consented. Written informed consents were obtained from the participants.

Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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