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Educational Intervention Involving Physical Manipulatives for Improving Grade 7 Learners' Spatial Reasoning Skills

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Abstract

Physical manipulatives enhanced knowledge acquisition by engaging learners in hands-on experiences that supported spatial reasoning. These tools allowed learners to see, touch, and manipulate objects, improving their ability to mentally rotate and visualize structures. This study challenged the assumption that most learners are purely visual by demonstrating that multisensory engagement—both sight and touch—improved retention. Specifically, it examined how educational activities using physical manipulatives enhanced the spatial reasoning skills of Grade 7 learners. A Quasi-Experimental Research Design was selected due to the structured selection of participants rather than random assignment. Purposive sampling was used to select Grade 7 learners enrolled in a public junior high school in Manila during the Academic Year 2023-2024. Participants engaged in immersive hands-on activities, such as "Six-Sided Puzzles," "How Many Cubes Are There?" and "Double-Sided Puzzles," over a one-week intervention period. An adapted Spatial Reasoning Instrument measured their spatial reasoning skills. Results showed a significant improvement in spatial reasoning among learners exposed to physical manipulatives, who outperformed the control group. Additionally, the experimental group's mental rotation ability scores were significantly higher than those of the control group. These findings suggested that integrating physical manipulatives into instruction enhanced spatial reasoning and cognitive development. This study highlighted the importance of incorporating hands-on learning tools into spatial reasoning instruction for long-term academic benefits.

Keywords: Physical Manipulatives, Spatial Reasoning Skills, Educational Intervention, Puzzles, Grade 7 Learners

1. Introduction

Spatial reasoning refers to a person's cognitive skill to visualize and manipulate spatial figures, understand relationships, and form shapes (Clement and Battista, 1992, as cited in Hartatiana et al., 2018). In the literature, the terms spatial reasoning, spatial skills, and spatial ability are often used interchangeably (Kurt et al., 2023). In the present study, the term spatial reasoning skills was used, acknowledging its overlap with spatial skills and spatial ability. The subcomponents of spatial reasoning include mental rotation, spatial orientation, and spatial visualization (Lowrie et al., 2018, as cited in Fujita et al., 2020). Mental rotation refers to the cognitive ability to picture how a two-dimensional shape or three-dimensional object would appear after being rotated by a particular angle (Shepard & Metzler, 1971, as cited in Fowler et al., 2022). Spatial orientation enabled an individual to determine their position in relation to the surrounding environment and could be enhanced through targeted training. It was considered an essential competency for STEM university programs focused on geospatial information (Carbonell-Carrera & Saorin, 2018). Finally, spatial visualization was recognized as a fundamental spatial reasoning skill and was essential for comprehending and participating in STEM-related activities (Arcavi, 2003; Ontario Ministry of Education, 2008; Ramful & Lowrie, 2015, as cited in Fowler et al., 2022).

Despite its importance, spatial thinking — the ability to recall, create, manipulate, and reason about spatial relationships — remained surprisingly underrepresented in modern mathematics curricula. In some regions, efforts were even made to reduce the presence of spatial thinking in math education (Gilligan-Lee, Hawes, & Mix, 2022). Nevertheless, for educators to effectively meet learning objectives, it was crucial that they had the necessary technological expertise in virtual and augmented reality (Serrano-Ausejo & Mårell-Olsson, 2024). Although immersive tools like VR and AR held promise for improving spatial skills, obstacles such as limited technology access and varying degrees of teachers' digital proficiency persisted.

The importance of these spatial thinking skills became evident when considering their strong link to performance, perseverance, and achievement in science, technology, engineering, and mathematics (STEM) education. Since STEM knowledge and skills were essential for building a well-prepared workforce both within and outside of STEM fields, spatial skills became a key area of focus in cognitive, developmental, and educational research (Uttal et al., 2024). Furthermore, these skills were crucial for both learning and utilizing mathematics (Muhammad et al., 2022). Indeed, fostering spatial reasoning skills was recognized as a key goal of mathematics education, spanning from kindergarten through to university (Septia et al., 2018).

Given their significance in mathematics learning, spatial reasoning skills played an especially vital role in the study of geometry, where visualizing two-dimensional (2D) and three-dimensional (3D) shapes was essential for grasping complex concepts. Through the study of geometry, students gained opportunities to deepen their understanding of mathematical relationships and improve their overall mathematical competence (Kurt et al., 2023). Furthermore, Asiamah and Fletcher (2023) argued that enhancing 2D and 3D spatial ability fostered student-centered learning in solid geometry, emphasizing the importance of interactive and engaging educational approaches.

To address the cognitive and affective challenges learners faced in learning geometry, physical manipulatives were employed in this study. Physical manipulatives were interactive learning tools like Geometric Solids Models, Tangrams, and Geoboards that educators used to help learners understand complex mathematical ideas. Although often associated with early childhood education, physical manipulatives remained valuable at higher grade levels, notably in subjects like algebra, geometry, and probability. For Grade 7 learners, these tools provided a concrete way to visualize abstract ideas, such as exploring three-dimensional shapes using solid geometric models. They made mathematics more engaging and comprehensive by allowing learners to see, touch, and manipulate objects to solve problems rather than relying solely on paper-and-pencil methods.

As learners progressed in their mathematical journey, physical manipulatives served as an intervention, helping them transition from concrete experiences to abstract and spatial reasoning. Taley (2023) emphasized that using manipulatives in mathematics education was critical for improving students' conceptual knowledge. These tools supported the learning process across different mathematical topics, including exploring spatial relationships, identifying and describing types of symmetry, developing spatial memory, and experimenting with transformations — all of which related to spatial reasoning skills.

The COVID-19 pandemic accelerated a shift toward digital learning, transforming education beyond traditional classroom setups and moving it to virtual platforms. Many schools adapted personalized learning approaches, allowing learners to learn at their own pace. However, this shift also brought challenges. While numerous programs were developed to illustrate geometry digitally, the complexity of navigating these programs posed difficulties for young learners. Moreover, not all schools could afford computer laboratories, and the lack of such facilities remained a significant issue in the Philippines.

During this time, many students struggled with limited access to reliable internet and digital devices, a challenge supported by Abelgas (2022). The study highlighted that junior high school learners in the Philippines faced unstable internet connectivity, inadequate technological devices, and unfavorable home learning environments, making it difficult to participate in online activities.

Additionally, several studies have highlighted the negative effects of digitization on learning. According to Pérez-Juárez et al. (2024), while technology promotes a sustainable and universally accessible educational model and helps learners engage in learning activities, it is also a significant source of distraction. Likewise, people often behave differently on social media compared to real-life interactions, and Sander (2024) reported that increased technology exposure is directly associated with decreased physical activity among school learners.

Timotheou et al. (2022) argued that the accelerated shift to digital learning during the COVID-19 pandemic raised questions about digitalization in schools. Many institutions lacked the necessary experience and digital infrastructure, resulting in inequalities and widening learning gaps. Students without reliable internet access or appropriate devices often struggled to complete their assignments, leading to lower academic performance and a higher risk of dropping out. This digital divide created significant barriers to ensuring equal educational opportunities for all students. Moreover, research by Lüdke et al. (2023) indicated that digital teaching methods may not effectively convey psychomotor skills, further emphasizing the limitations of purely digital learning environments.

Given these challenges, there was a pressing need for additional educational tools that enabled learners to visualize two-dimensional and three-dimensional figures without relying on complex software or facing limitations due to inadequate computer access. Despite the availability of various electronic tools and programs, many learners still preferred hands-on learning approaches.

In this era of digitization, physical manipulatives remained essential for Grade 7 geometry lessons. They bridged the gap between concrete and abstract concepts by helping learners transition from tangible experiences to abstract reasoning. Physical manipulatives enhanced conceptual understanding, promoted active learning, supported diverse learning styles, and built problem-solving skills (Knaub, 2024). To address this gap, the present study aimed to demonstrate that most learners were not merely visual learners; they retained information more effectively when they could see, and touch materials rather than just observe them. Specifically, this study sought to investigate the impact of educational intervention involving physical manipulatives on improving Grade 7 learners' spatial reasoning skills.

This study was significant because it addressed a crucial gap in mathematics education, particularly in spatial reasoning, by examining the role of physical manipulatives in enhancing learners' spatial reasoning skills. Given that spatial reasoning skills were fundamental to success in STEM fields, improving these skills in early education had long-term benefits for students' academic and career pathways. Moreover, with the challenges posed by digital learning—such as accessibility issues and reduced hands-on interaction—this study underscored the continued relevance of tangible learning tools in fostering engagement and deeper understanding. By providing empirical evidence on the effectiveness of physical manipulatives in Grade 7 geometry lessons, the study contributed to educational research, informed curriculum development, and offered practical insights for educators seeking to optimize student learning experiences.

2. Methodology

2.1. Research Design

The researcher used a Quasi-Experimental Research Design, which studied natural variations in the main independent variable. This design created experimental-like conditions where some participants received treatment while others did not, but without random assignment. Although quasi-experiments resembled true experiments in structure, they lacked the strict random assignment of participants (Cook & Wong, 2008; Gopalan et al., 2020; Kirk, 2009, as cited in Rogers & Révész, 2019).

This design was well-suited for this study as it assessed the effectiveness of an educational intervention using physical manipulatives. It enabled a comparison between an experimental group, which received the intervention, and a control group, which did not.

The researcher specifically used the Pretest-Posttest Control Group Design. In this approach, both groups took a pretest before the intervention and a posttest afterward. This method confirmed that the groups were comparable before treatment and evaluated the intervention's immediate effect on the outcome variable(s) (Cook & Wong, 2008, as cited in Rogers & Révész, 2019).

2.2. Participants of the Study

The participants of the study were Grade 7 learners enrolled in a public junior high school in Manila during the Academic Year 2023–2024. A purposive sampling technique was employed to select the participants, after which the researcher randomly assigned one section as the experimental group and the other as the control group using a lottery method.

The control group initially consisted of 41 learners, while the experimental group included 45 learners. Learners whose guardians did not sign the informed consent form, as well as those who did not sign the informed assent form, were removed from the list of participants. Additionally, learners who accumulated more than five absences were automatically excluded from the study. After excluding learners who did not meet these criteria and ensuring comparability following the pretest, the control group was narrowed down to 34 learners, while the experimental group was reduced to 38 learners.

2.3. Research Instruments

The instrument used in this study was the Spatial Reasoning Instrument (SRI), was adopted from the study by Ramful et al. (2017) focused on the measurement of spatial ability of middle school learners aged 11-13. The SRI assessed the spatial reasoning abilities of participants through a survey consisting of 30 multiple-choice questions, designed to be completed within 45 minutes. The instrument was divided into three sub-constructs: Mental Rotation, Spatial Orientation, and Spatial Visualization, each worth 10 points. Although the reliability of the individual sub-constructs was not very high, the overall SRI had a Cronbach's alpha value of 0.849. The difficulty levels for mental rotation ranged from 0.28 to 0.84, while those for spatial visualization ranged from 0.35 to 0.85. Notably, spatial orientation items exhibited relatively high item difficulty values, ranging from 0.60 to 0.92.

In this study, scores were interpreted as follows: a score of 0 to 10 indicated a "low" level of spatial reasoning skills, a score from 11 to 20 signified an "average" level, and a score between 21 and 30 was considered "high" spatial reasoning skills. In addition, a score of 0 to 3 indicated a "low" level of mental rotation, spatial orientation, and spatial visualization, a score from 4 to 7 signifies an "average" level, and a score from 8 to 10 was considered "high" mental rotation, spatial orientation, and spatial visualization skills.

2.4. The Physical Manipulatives

The physical manipulatives used were designed by the researcher with unique property and specific usage. These included magnetic manipulative cubes, manipulative frames, and manipulative puzzle pieces.

2.4.1. Magnetic Manipulative Cubes

The magnetic manipulative cubes were 24 small wooden cubes, each measuring 1.6 cm on each side and covered with a thin 0.1 cm magnetic sheet and images. The difficulty of the cube designs depended on the grade level of the learners. The magnetic manipulative cubes were used in the activities “Six-Sided Puzzle”, and “How Many Cubes are there?”

2.4.2. Manipulative Frames

The manipulative frames consisted of ten transparent frames, each measuring 9 x 7.2 x 0.8 cm, with a strong magnet at the bottom that allowed them to stand on metal surfaces and were used in the activity Double-Sided Puzzle.

2.4.3. Manipulative Puzzle Pieces

The manipulative puzzle pieces were the pieces of the Double-Sided Puzzle. There were 10 sets of manipulative puzzle pieces with varying shapes and sizes. The color and pattern on the front and back of each piece provided clues to solve the puzzle. These were positioned inside the manipulative frame so that each hint could be easily seen from the rear. The difficulty of the puzzle designs depended on the grade level of the learners.

Figure 1. Physical Manipulatives Used in the Intervention

2.5. Educational Intervention

The following were the educational intervention that incorporated physical manipulatives, which were used to enhance the spatial reasoning skills of Grade 7 learners and were designed in alignment with the needs of the physical manipulatives.

2.5.1. Six-Sided Puzzle

This activity utilized the 24 magnetic manipulative cubes. By flipping them in different ways, learners can create five different images. They arranged the cubes to form these images, using the other faces as a guide to complete the puzzle. If two cubes repelled each other, it meant they were not connected to each other. Learners identified the image formed and wrote it on a sheet of paper.

2.5.2. How many cubes are there?

This activity utilized the 24 magnetic manipulative cubes. Using the magnetic manipulative cubes, the learners were instructed to construct figures made up of stacked cubes, and then the learners determined the total number of magnetic manipulative cubes used to form each figure.

2.5.3. Double-Sided Puzzle

This activity utilized 10 manipulative frames and the corresponding manipulative puzzle pieces. The manipulative frames were placed upright on a metallic table. The learners were then instructed to assemble the manipulative puzzle pieces into each manipulative frame to create images. One side of the manipulative puzzle pieces served as a guide for solving the images on the reverse side. In addition, there were clues to discover as the activity progressed.

2.6. Data Collection

This study investigated the effectiveness of an educational intervention utilizing physical manipulatives by comparing the spatial reasoning skills (SRS) of two Grade 7 classes. Both classes, taught by the same teacher, were assigned to the control group (CG) and the experimental group (EG). While both groups followed the traditional method of teaching and learning Geometry, the EG integrated the developed intervention with physical manipulatives into their learning process. The study was divided into three stages: the pre-intervention stage, the intervention stage, and the post-intervention stage.

During the pre-intervention stage, the Spatial Reasoning Instrument (SRI) was administered to the participants as a pretest to assess the SRS of the participants in the CG and EG. The participants were given 45 minutes to complete the SRI. The results of the SRI pretest were used to establish the comparability of the two groups.

The intervention stage began by dividing the EG into smaller groups to facilitate cooperative learning. The educational intervention utilizing physical manipulatives as motivational activities —(1) Six-Sided Puzzles, (2) How Many Cubes Are There?, and (3) Double-Sided Puzzle—were introduced to the EG prior to the lesson. The researcher provided guided activity sheets explaining how to perform the activities. After a week of intervention, the post-intervention stage began with the administration of the SRI as a posttest to both the CG and EG. The results of the SRI posttest were used to compare the SRS of (1) the CG before and after traditional instruction, (2) the EG before and after the intervention, and (3) the CG and EG after the intervention.

The results of the SRI pretest and posttest served as the sole source of data for this study.

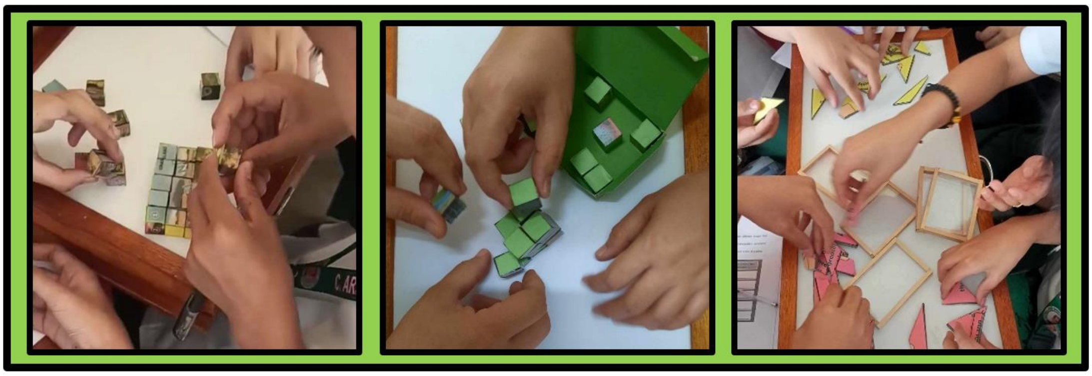

Figure 2. Learners Participating in Intervention Activities

2.7. Ethical Considerations

Before conducting the study, the researcher secured permission from all relevant authorities. Approval was first obtained from the CEU Institutional Ethical Review Board (IERB) to ensure that the research met ethical standards. Additionally, a permit was granted by the DepEd NCR Schools Division Office of Manila, allowing the study to be conducted in a selected public junior high school. In coordination with the principal, the Mathematics Subject Head, and the mathematics teacher handling the selected learners, the researcher ensured a smooth process for conducting the study.

The study adhered to strict ethical guidelines to protect the rights and well-being of all participants. Since the learners were between 13 and 15 years old, both informed consent from parents and assent from the learners were obtained before the research began.

3. Results and Discussion

The Spatial Reasoning Test results for both the control and experimental groups in this study were summarized in Table 1.

Table 1. Learners' Level of Spatial Reasoning Skills

Spatial Reasoning Sub-components	Control Group						Experimental Group					
	Pretest			Posttest			Pretest			Posttest		
	Mean	SD	V.I.	Mean	SD	V.I.	Mean	SD	V.I.	Mean	SD	V.I.
1. Mental Rotation	2.24	1.37	Low	2.41	1.50	Low	2.86	1.57	Low	3.69	1.94	Average
2. Spatial Orientation	5.62	1.56	Average	6.32	1.77	Average	5.61	2.45	Average	6.28	1.97	Average
3. Spatial Visualization	2.44	1.08	Low	2.44	1.62	Low	2.75	1.46	Low	3.03	1.52	Low
4. Overall Spatial Reasoning Skills	10.29	2.70	Average	11.18	3.42	Average	11.22	4.19	Average	13.00	4.04	Average

As shown in Table 1, mental rotation, spatial orientation, and spatial visualization were the components of spatial reasoning skills, which assessed an individual's ability to manage and comprehend objects in space. In the mental rotation pretest, the control group achieved an average score of 2.24 (SD = 1.37), while the experimental group scored slightly higher, with a mean of 2.86 (SD = 1.57). These scores indicated that both groups exhibited relatively low levels of mental rotation ability. The results of the posttest showed that the mean score of the control group improved to 2.41 (SD = 1.50), and the experimental group showed a more notable improvement with a mean score of 3.69 (SD = 1.94). The posttest results indicated that the experimental group's score had improved to an "average" level, while the control group's score remained classified as "low."

Mental rotation skills are highly relevant in fields such as engineering, architecture, and surgery. Learners with "low" to "average" mental rotation skills were likely to face ongoing challenges when dealing with more complex rotations, particularly those involving three-dimensional figures. The characteristics of the learners in this study aligned with the findings of Winarti and Patahuddin (2019), which reported that in one of the most disadvantaged areas of Indonesia, West Nusa Tenggara, the average score on a mental rotation test for both boys and girls was classified as "low."

As gleaned in Table 1, the mean score of the control group in the pretest of spatial orientation was 5.62 (SD = 1.56), while the mean score of the experimental group in the pretest of spatial orientation was 5.61 (SD = 2.45). These scores implied that both groups demonstrated an "average" level of spatial orientation skills. Meanwhile, the mean score of the control group in the posttest of spatial orientation improved to 6.32 (SD = 1.77), while the mean score of the experimental group in the posttest of spatial orientation also improved to 6.28 (SD = 1.97). Even though both groups showed improved scores, their performance still lingered within the "average" category of spatial orientation skills.

Spatial orientation referred to a person's capacity to identify their position in space and navigate around it. This ability was crucial in driving, piloting, and even map reading. Therefore, high spatial orientation skills implied good performance in maritime and aviation fields. According to Ishikawa (2019), spatial orientation and navigation could be problematic for some people even with physical maps or satellite navigation.

The last sub-component of spatial reasoning is spatial visualization. Spatial visualization is the ability to manipulate, combine, or dismantle spatial information mentally, which is the key for understanding how different parts of an object fit together. This skill is essential in civil, electrical, electronics, and mechanical engineering.

As depicted in Table 1, the mean score of the control group in the spatial visualization pretest, was 2.44 (SD = 1.08), while the mean score of the experimental group was 2.75 (SD = 1.46). These scores indicated that both groups displayed quite "low" levels of spatial visualization ability. In the posttest, the mean score of the control group remained the same at 2.44 (SD = 1.62), and the mean score of the experimental group slightly improved to 3.03 (SD = 1.52). Similarly, both results were interpreted as "low." The results were similar to the study of Kurt et al. (2023), in which the average scores for mental rotation and spatial visualization were lower than those for spatial orientation.

According to Sorby and Panther (2020), the development of spatial reasoning skills was critical to students' success in national exams such as high school entrance exams or international exams such as PISA and TIMSS.

Finally, in terms of the overall spatial reasoning skills, the control group achieved a mean score of 10.29 (SD = 2.70) in the pretest, while the experimental group had a slightly higher mean score of 11.22 (SD = 4.19). These initial scores suggested that both groups demonstrated an "average" level of spatial reasoning skills. In the posttest, the mean score of the control group improved to 11.18 (SD = 3.42), and the experimental group showed a more notable improvement with a mean score of 13.00 (SD = 4.04). Although both groups exhibited an upward trend in their posttest scores, their performance remained within the "average" category of spatial reasoning skills.

Having average spatial reasoning skills entailed that learners could perform well in both academic and spatial tasks, but they might face limitations in a substantially specialized field that required 3D manipulation. However, the study of Uttal et al. (2013) indicated that spatial skills were essential for success in STEM fields and that enhancing these skills through training intervention could lead to improved spatial abilities, which supports the findings of this study showing notable improvement in the experimental group's spatial reasoning scores.

Table 2. Comparison of Spatial Reasoning Skills Between Control and Experimental Groups Pre- and Post-Intervention

Spatial Reasoning Sub-components	Control Group						Experimental Group					
	Pretest		Posttest		t-value	p-value	Pretest		Posttest		t-value	p-value
	Mean	SD	Mean	SD			Mean	SD	Mean	SD		
1. Mental Rotation	2.24	1.37	2.41	1.50	-0.525	p=0.603>0.05	2.86	1.57	3.69	1.939	-2.808	p=0.008<0.05
2. Spatial Orientation	5.62	1.56	6.32	1.77	-2.694	p=0.011<0.05	5.61	2.45	6.28	1.966	-2.125	p=0.041<0.05
3. Spatial Visualization	2.44	1.08	2.44	1.62	0	p=1.00>0.05	2.75	1.46	3.03	1.521	-0.881	p=0.384>0.05
4. Overall Spatial Reasoning Skills	10.29	2.70	11.18	3.42	-1.33	p=0.193>0.05	11.22	4.19	13.00	4.036	-2.546	p=0.015<0.05

Table 2 displayed the comparison of learners' mathematical spatial reasoning skills in both the control and experimental groups before and after the using the physical manipulatives.

The control group had a pretest mean score of 2.24 (SD = 1.37) in mental rotation, which slightly improved to 2.41 (SD = 1.50) in the posttest. Despite this improvement, the difference in the control group's mental rotation scores between the pretest and posttest was not statistically significant ($t = -0.525$, $p > 0.05$). The experimental group's mental rotation pretest mean score was 2.86 (SD = 1.57), which improved to 3.69 (SD = 1.94) in the posttest. This increase in the mean score was found to be statistically significant ($t = -2.808$, $p < 0.05$), indicating that the intervention had a meaningful impact on enhancing the learners' mental rotation skills.

Piri and Cagiltay (2023) found that 3-D visualization improved mental rotation, directly supporting the experimental group's significant improvement and reinforcing the effectiveness of physical manipulatives over traditional 2-D methods.

In terms of spatial orientation, Table 2 showed that the control group had a pretest mean score of 5.62 (SD = 1.56) and improved to a posttest mean score of 6.32 (SD = 1.77). This improvement was statistically significant ($t = -2.694$, $p < 0.05$). Similarly, the experimental group's pretest mean score for spatial orientation was 5.61 (SD = 2.453), which improved to 6.28 (SD = 1.97) in the posttest. This improvement was also statistically significant ($t = -2.125$, $p < 0.05$), implying that both groups showed meaningful progress in spatial orientation. These findings indicated that studying geometry contributed to the development of spatial orientation skills.

The NCTM Standards (2000) emphasized using geometry and transformations to describe spatial relationships, which aligned with and supported the statistically significant improvement observed in both groups' spatial orientation scores.

Regarding spatial visualization, the control group had a pretest mean score of 2.44 (SD = 1.08), which remained unchanged at 2.44 (SD = 1.62) in the posttest. Since there was no variation, the spatial visualization scores for the control group between the pretest and posttest were not statistically significant ($t = 0.000$, $p > 0.05$). On the other hand, the experimental group's pretest mean score for spatial visualization was 2.75 (SD = 1.46), which improved to 3.03 (SD = 1.52) in the posttest. However, despite this improvement in the experimental group's spatial visualization scores, the difference was not statistically significant ($t = –0.881$, $p > 0.05$). This suggested that the intervention did not have a significant effect on improving the learners' spatial visualization skills.

Alqahtani et al. (2017) noted traditional tools were insufficient for improving spatial visualization, which was consistent with the lack of significant improvement seen in the experimental group's scores.

As shown in Table 2, the control group had a pretest mean score of 10.29 (SD = 2.70) in spatial reasoning skills, which slightly improved to 11.18 (SD = 3.42) in the posttest. However, this slight difference in the control group's spatial reasoning scores between the pretest and posttest was not statistically significant ($t = –1.330$, $p > 0.05$). In contrast, the experimental group had a pretest mean score of 11.22 (SD = 4.19), which improved to 13.00 (SD = 4.04) in the posttest. This improvement in the experimental group's scores was statistically significant ($t = –2.546$, $p < 0.05$). These results indicated that the intervention using the physical manipulatives effectively enhanced the spatial reasoning skills of the learners.

Hawes et al. (2022) showed that concrete materials like manipulatives were more effective, strongly supporting the experimental group's significant improvement in spatial reasoning and highlighting the importance of hands-on learning tools.

Table 3. Comparison of Spatial Reasoning Skills Between Control and Experimental Groups Post-Intervention

Spatial Reasoning Sub-components	Control Group		Experimental Group		t-value	p-value	Effect Size (Cohen's d)
	Posttest		Posttest				
	Mean	SD	Mean	SD			
1. Mental Rotation	2.41	1.50	3.69	1.94	-3.083	p=0.003<0.05	0.74
2. Spatial Orientation	6.32	1.77	6.28	1.97	0.102	p=0.919>0.05	0.02
3. Spatial Visualization	2.44	1.62	3.03	1.52	-1.564	p=0.123>0.05	0.38
4. Overall Spatial Reasoning Skills	11.18	3.42	13.00	4.04	-2.035	p=0.046<0.05	0.49

Table 3 presented a comparison of the spatial reasoning skills of the control and experimental groups. Following the posttest, the control group recorded a mean score of 2.41 (SD = 1.50) on the mental rotation test, whereas the experimental group obtained a higher mean score of 3.69 (SD = 1.94). The variation in posttest mean scores for mental rotation between the two groups was found to be statistically significant ($t = –3.083$, $p < 0.05$). The effect size (Cohen's $d = 0.74$) suggests a moderate to large impact of the intervention on participants' ability to mentally manipulate objects in space. This result aligned with the findings of Gilligan-Lee, Hawes, Williams, et al. (2023). Gilligan-Lee et al. (2023), which demonstrated that both embodied and non-embodied spatial training methods improved spatial skills, with embodied training using physical manipulatives producing deeper spatial processing.

The spatial orientation posttest mean score of the control group was 6.32 (SD = 1.77), while the experimental group's posttest in spatial orientation attained a slightly lower mean score of 6.28 (SD = 1.97). The difference in spatial orientation posttest mean scores between the control and experimental groups was not statistically significant ($t = 0.102$, $p > 0.05$). The effect size (Cohen's $d = 0.02$) was negligible, suggesting that the intervention had little to no effect on this spatial orientation. This result contradicted Wulandari (2020), who reported that students' spatial orientation improved following a spatial intervention, even though their performance remained below standard overall.

The spatial visualization posttest mean score of the control group was 2.44 (SD = 1.62), while the experimental group's posttest in spatial visualization attained a higher mean score of 3.03 (SD = 1.52). The difference in spatial visualization posttest mean scores between the control and experimental groups was not statistically significant ($t = -1.564$, $p > 0.05$). The small to moderate effect size (Cohen's $d = 0.38$) suggests some potential for improvement, though not strong enough to be conclusive. This also echoed the findings of Entera and Belgira (2021), showing similar score ranges and median values for both groups after a spatial puzzle intervention, suggesting limited improvement in spatial visualization.

The overall spatial reasoning posttest mean score of the control group was 11.18 (SD = 3.42), while the experimental group's posttest in spatial reasoning attained a better mean score of 13.00 (SD = 4.04). The difference in spatial reasoning posttest mean scores between the control and experimental groups was statistically significant ($t = -2.035$, $p < 0.05$). The effect size (Cohen's $d = 0.49$) suggests a moderate impact, indicating that while the intervention contributed to the enhancement of spatial reasoning, its effects were primarily driven by improvements in mental rotation rather than in spatial orientation or visualization. This result was supported by Lowrie et al. (2018), who found that students receiving targeted spatial reasoning intervention outperformed those receiving standard mathematics instruction, highlighting the effectiveness of structured spatial reasoning activities.

4. Conclusion

This study underscored the importance of targeted intervention in developing specific spatial reasoning skills. Differences between groups suggested that instructional approaches involving physical manipulatives more effectively enhanced mental rotation and overall spatial reasoning, while others needed refinement to improve spatial visualization. The hands-on nature of these manipulatives likely provided tangible experiences that supported cognitive processes involved in spatial tasks. This highlighted the need for educators to tailor strategies addressing distinct components of spatial ability for comprehensive skill development.

Despite promising results, the study had limitations. The one-week intervention period may not have allowed participants sufficient time to fully develop and consolidate spatial skills. A longer duration might yield more solid and sustained improvements, particularly in spatial visualization.

These findings had significant implications for educational practice, especially in fields like mathematics, engineering, and the sciences, where spatial reasoning is essential. Carefully designed intervention, particularly those using physical manipulatives, showed meaningful improvements, emphasizing the value of incorporating spatial training into curricula. Future research should explore the impact of extended training periods on different aspects of spatial reasoning, identify effective methods for strengthening spatial visualization, and investigate the long-term retention of these gains across various learning contexts.

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