

Spatial Visualization Skills in High School Students Through the Integration of Spatial Vis

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Abstract. This study investigates the integration of Spatial Vis—an accessible digital tool—into the exploratory technical drawing curriculum for Grade 8 Technology and Livelihood Education (TLE). Specifically, it assesses the application's effectiveness in enhancing spatial visualization skills and educational performance within the orthographic and isometric drawing lessons. The research was conducted with (45) Grade 8 students at Abuno National High School to address the need for innovative teaching methods in this area. A quasi-experimental design was utilized to evaluate the impact of Spatial Vis, delivered via mobile and desktop applications, compared to a traditional instructional approach. Spatial visualization ability was measured using the Purdue Spatial Visualization Test: Rotations (PSVT: R), administered before and after the intervention. The dependent variable was the gain in spatial visualization scores, with the independent variable being the mode of instruction (traditional, mobile, desktop). While the analysis between the three instructional methods in terms of their impact on spatial visualization gains were not significant, within-group improvements demonstrated a statistically significant improvement in the mobile Spatial Vis group ($t=-3.322, p=0.006$). This finding highlights the potential of the mobile Spatial Vis application to be utilized in the classroom for developing students' spatial visualization skills.

Keywords: Spatial Visualization, Spatial Skills, Orthographic Drawing, Isometric Drawing, Spatial Vis

1. Introduction

Creating effective and engaging lessons for large classes presents a major challenge for technology educators, as they must balance diverse learning styles and maintain student interest. The complexity often arises because the meanings of concepts are shaped by students' perspectives, not just the words themselves. Communication requires aligning these individual interpretations. A particular challenge is teaching technical planning and

mechanical drawing, which rely heavily on lines and figures to convey abstract ideas. Technical drawings have been essential because they provide the students with the basic framework they need to visualize and understand the intended space. They serve as tools for analysis, communication, and problem-solving in addition to being representations or illustrations.

Prior to studying intricate and complex illustrations, students can manipulate and comprehend the fundamental concepts through the orthographic and isometric lessons in engineering drawing. Engineering and drafting professionals use the engineering drawings as their "language" to convey technical concepts, and they are created in accordance with the uniform standards established. The ability to read and draw designs is therefore a fundamental skill that every technician must have (Bairaktarova et al., 2015).

Orthographic drawings are a type of 2D representation that show an object's height and length on a flat surface, without showing depth. In contrast, 3D drawings, such as isometric drawings, illustrate an object's depth, width, and height, providing a more complete visual representation (SANS Machining, 2024).

Moreover, Ainsworth and Scheiter (2021) found that teaching orthographic and isometric drawing on a simple chalkboard has made it challenging for pupils to understand the ideas because different students have varying levels of proficiency. Students frequently have trouble with mental rotation and spatial reasoning in certain illustrations which makes comprehension challenging.

This challenge emphasizes how crucial it is for educators to develop and integrate creative and successful strategies in the class. Since 21st century learners are becoming more interested in digital platforms, technology teachers should utilize tools to make the lesson more interesting while teaching the principles and foundations of technical drawing.

Mental manipulation is important because it enhances our understanding and critical thinking skills of complex spatial relationships. Tasks requiring creativity and critical analysis are better performed by people who can see how an object might alter when modified or how it might appear from various perspectives. This is founded in Dr. Howard Gardner, the founder of the multiple intelligence theory, which states that intelligence is "the capacity to acquire and apply knowledge." These intelligences are determined when people engage in culturally significant activities that aid in the development of unique cognitive processes (Cavas et al., 2020).

Of the eight types of intelligence, spatial intelligence is one. Spatial intelligence is one facet or type of intelligence. The ability to reproduce one's visual experience and reasoning regarding shape, measurement, portrayal, and navigation is the most widely used definition of spatial intelligence.

Spatial reasoning, the ability to mentally manipulate and transform spatial information, has long been recognized as an essential component of mathematical and scientific thinking (Battista et al., 2018). Creating and modifying mental pictures of objects in space from fixed or shifting viewpoints allows one to reason about the objects and actions on them both when they are visible and when they are not. Spatial visualization allows one to project what will happen when objects are subjected to spatial actions. Spatial visualization includes visualizing a three-dimensional object from its orthographic projections and vice versa, visualizing how objects rotate in two and three dimensions, visualizing how two-dimensional patterns can be folded to create three-dimensional boxes and vice versa, and visually deconstructing and reassembling shapes into their individual parts.

As stated by Uttal et al. (2012), higher spatial skills are linked to improved success in the STEM field. A greater comprehension of the dynamics involved in engineering and design is made possible by this mental manipulation.

Spatial abilities, mental rotation and spatial visualization, have been linked to success and pursuit of careers in science, technology, engineering, and mathematics fields (Clifton et al., 2016). This proves that it is a reliable indicator of individual variations and personal

quality. It includes the ability to understand and control the spatial interactions among objects, manipulate mental representations and imagery of visual information and appropriately perceive visual images (Khine, 2016). Research shows strong links between spatial ability and achievement in science, technology, engineering, and math. These skills can be improved with practice and training. There's growing interest in developing spatial reasoning to help identify talented students and guide them toward STEM careers, which are essential in today's tech-focused world. Moreover, these skills are connected to gender differences, highlighting the need to nurture them across all groups.

Verdine et al. (2017) states that people may grasp STEM concepts quickly and generate new ideas by using their capacity to comprehend and depict mental and physical spatial representations. Learning would presumably benefit individuals who are more adept at comprehending, modifying, or producing these alignments. Making, analyzing, and visualizing modifications to spatial representations would undoubtedly aid beginners in understanding many intricate ideas included in STEM curriculum, even though such significant insights are uncommon.

Hawes et al. (2017) investigated the development of spatial visualization skills in Canadian kindergarten and early elementary students (ages 4-7). Teachers received training and created lesson plans designed to teach geometry through a spatial lens. Comparing intervention and control groups, the study found significant improvements in spatial language, visual-spatial geometry understanding, and object rotation abilities in the students who received the specialized instruction.

A key component of learning that affects many different subject areas is spatial reasoning. It elevates the capacity to manipulate and visualize information, which is needed for creative thinking and problem-solving in a variety of areas. Through practice in different activities and exercises, educators may help learners build spatial skills, which will enhance their cognitive abilities overall and prepare them for a variety of pathways and possibilities in the fields they're going to take. Moreover, fostering these skills in all students promotes inclusivity and helps bridge gaps in educational achievement. With that, spatial reasoning plays a big role in enhancing learning and understanding across multiple disciplines.

Hence, spatial visualization helps in understanding complex design, generating innovative solutions, and predicting results. in three dimensions. But there remains a lack of research on effective pedagogical strategies that leverage technology to improve these skills in large classroom settings. The need for innovative solutions is further underscored by the increasing interest of students in digital platforms, which can be harnessed to create more engaging learning experiences.

Because of this, the teacher's role is essential in teaching both the lesson and the fundamentals. The utilization of various techniques and media in the classroom, as well as the application of pertinent learning theories and principles, must all be considered when developing an appropriate teaching approach.

As previously said, students were using digital platforms, making it challenging to us to maintain their focus in the lesson. Haleem et al. (2022) states that incorporating technology into the classroom gives students an interesting experience that keeps them focused on the material without becoming distracted. Students may find learning engaging and enjoyable if projectors, laptops, and other state-of-the-art technology are used in the classroom. Many web programs are available to help students improve their spatial skills; however, the researcher is going to utilize Spatial Vis (Cowan et al., 2017).

The researcher integrated technology-based learning into the classroom using a spatial visualization application. The application called Spatial Vis developed by eGrove Education is a great tool to facilitate learning in technical drawing class. This educational technology, compatible with Android, Apple, and Chromebook devices, facilitates the

development of spatial reasoning skills by enabling students to manipulate and sketch two- and three-dimensional objects. (Delson et al., 2015).

Spatial Vis is a personalized learning environment developed by eGrove Education, Inc. The purpose of this application is to improve students' spatial visualization skills. The focus of this application is freehand drawing of 2D and 3D perspectives, which is an essential ability for enhancing critical thinking, problem solving, and STEM field readiness. According to Cowan et al. (2017), this innovative application began a trial in 2014 and underwent upgrades till 2017.

This approach has the major benefit of giving students quick feedback, which boosts their motivation and engagement. Students can work freely on both mobile and web platforms. With ten courses covering orthographic projections and rotations, Spatial Vis used a gamified approach. Students received quick feedback through automated grading, and the app provided recommendations to increase their interest in the material.

The app includes features like "undo" and "redo" for easy manipulation of sketches, helping students to improve their visualizations. If a student submits an incomplete sketch, hints are provided to guide them towards the correct solution. Lastly, Spatial Vis incorporates a star-based feedback system, offering a clear visual representation of the student's sketching accuracy and overall progress.

The Getting Started button is visible upon launching the application at <https://egrove.education/>. It gives thorough information in this area and explains the purpose of the application. Additionally, it referenced other studies that support the idea that applications like these improve student engagement. The application in its latest version also has features in how teachers and learners can access the account. It's in free mode, Individual Student and Classroom License (Cowan et al., 2017).

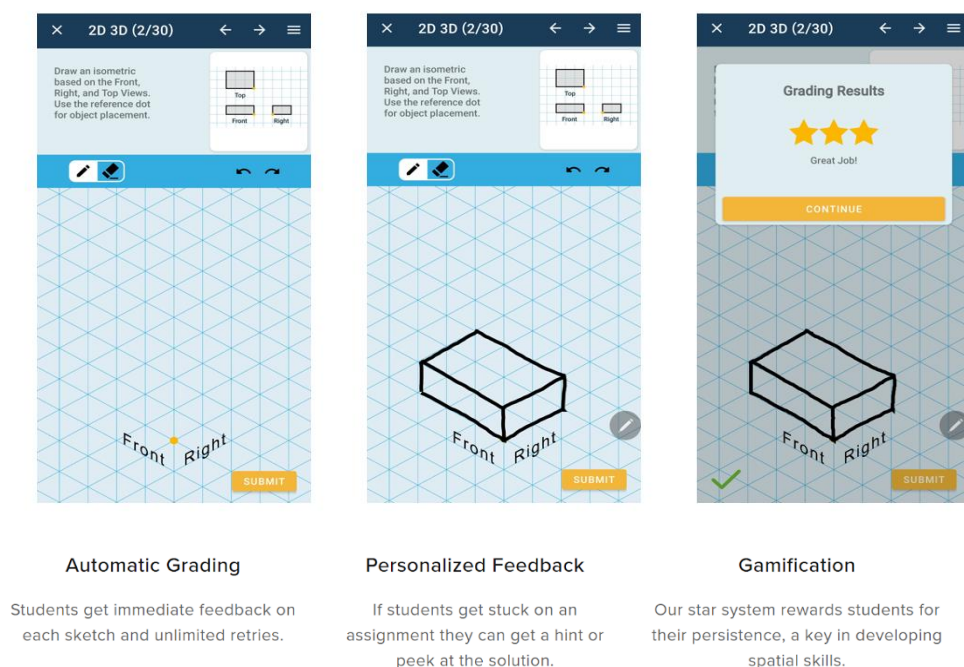


Figure 1. Spatial Vis Sketching Application

This research has been granted access to the full features of Spatial Vis, including both mobile and web versions. This access allows students to engage with a wider range of lessons, activities and utilizing the comprehensive feedback and assessment tools available within the application. This opportunity enables a more in-depth exploration of Spatial

Vis's potential to enhance students' understanding of orthographic and isometric projections and provides valuable insights into the pedagogical applications of this technology without any financial burden to the school or participants.

The software provides immediate feedback and automated grading, effectively assisting the teacher in both traditional classroom settings and remote learning environments. Thus, the application incorporates gamified elements to enhance student engagement and motivation.

This study specifically seeks to use and incorporate Spatial Vis in Orthographic and Isometric lessons, test and implement Spatial Vis for students both mobile and desktop platforms and traditional way of teaching orthographic and isometric projection and analyze the differences between the students pre- and post-test results after using Spatial Vis and traditional teaching methods.

The Spatial Vis application has been the subject of ongoing research since its initial trial phase, establishing its credentials as a dedicated, evidence-based tool for developing spatial visualization skills. The application, developed by eGrove Education, Inc., has undergone several upgrades since its inception to enhance its effectiveness and features. Prior studies implementing Spatial Vis have generally affirmed its potential to improve student performance in technical and engineering disciplines, primarily through its interactive environment and immediate feedback mechanisms.

A study of Delson and Van Den Einde (2015) focusing on the Spatial Visualization Trainer (SVT) App a predecessor to Spatial Vis used on a touchscreen device (iPad), this study highlighted the superior pedagogical value of non-multiple-choice sketching assignments which require students to synthesize full solutions. Performance metrics for students who began with low pre-test scores showed a dramatic 43% increase in post-test results, underscoring the app's potential as an intervention tool for at-risk and underrepresented learners. The research also defined the "peeking metric" (the likelihood of viewing the solution) as a crucial indicator of perseverance and engagement, which could be used to identify struggling students early in the course.

Van Den Einde et al. (2017) mentioned identified persistence as the critical factor differentiating successful learners from those who fail to gain skills using the Spatial Vis application. Non-improving students tended to use the Peek feature as a "crutch," by passing the necessary cognitive struggle. Consequently, the study justified the implementation of the gamification system and the Hint as an intermediate step to actively encourage sustained, independent effort before accessing the solution. Following these design changes, subsequent trials demonstrated a substantial increase in post-test scores for low-skilled students and a 92% increase in the class's persistence metric.

Hoople et al. (2018) examined the impact of eGrove Education's Spatial Vis touchscreen application for teaching spatial visualization. The research focused on the fact that spatial skills are correlated with success in engineering, yet often not explicitly taught. The study used a controlled trial (n=55) where the app was assigned as homework to the experimental group. The analysis focused specifically on low-performing students (those scoring 70% on the PSVT: R, a reliable, well-validated instrument). The key finding for this low-performing group was the remarkable progress shown by the experimental group: 62% of app users raised their test scores above 70%, compared to only 14% in the control group. While the overall gain difference between the experimental and control groups was statistically insignificant, the results strongly suggest that the Spatial Vis app is a promising intervention for training spatial visualization skills, particularly for those students with limited prior experience.

A case study of Van Den Einde et al. (2022) focused on using the Spatial Vis Computer Based Learning (CBL) system—which automatically grades sketches and provides hints—to teach spatial visualization in an introductory engineering class (140 students). While Spatial Vis is generally effective, the study noted that some students fail to improve

their PSVT: R post-test scores despite using the tool. The research aimed to understand this learning process by performing a detailed case study on five selected students who started with low PSVT: R pre-test scores.

The analysis evaluated their orthographic projection errors, hint usage, and persistence. The key finding was that the two students who showed high persistence (completing assignments correctly without asking for hints) achieved significant post-test improvements. Conversely, one student who tried to "game the CBL system" and demonstrated low persistence saw no significant gain. The study concluded with recommendations for improving the CBL environment, emphasizing the need for data mining and research into instructional design and feedback for all students.

While previous research has established the fundamental efficacy of the Spatial Vis application in increasing persistence and improving performance in low-achieving, university-level engineering students, a gap remains in understanding the influence of the instructional delivery platform itself. No controlled study has yet isolated and compared the differential impact of the mobile touchscreen interface versus the desktop interface on learning outcomes, engagement, and platform-specific usability challenges among high school students in a non-engineering context. This study addresses this gap by directly comparing the two modalities to provide evidence-based recommendations for the optimal implementation of digital spatial training.

2. Methodology

2.1 Research Design

This research explored the potential of Spatial Vis to enhance spatial reasoning skills in students of Abuno National High School particularly, Grade 8 students who are studying exploratory courses in TLE. To give a thorough grasp of how the interactive orthographic and isometric drawing application, Spatial Vis works, the researcher will use a quasi-experimental design.

Pre-test and post-test results, utilizing the Purdue Spatial Visualization Test: Rotations (PSVT: R) (Yoon, 2011) were adapted in this study and were compared in the quantitative component's quasi-experimental design.

2.2 Research Locale and Participants

The research was conducted at Abuno National High School, specifically among (45) forty-five students from Grade 8 students enrolled in Technology and Livelihood Education during the fourth quarter of academic year 2024–2025. The participant pool includes high-achieving and low-achieving learners to ensure a diverse representation. The three groups EG (experimental group) (1) Students on mobile devices, EG (experimental group) (2) Students on desktop computers, and CG (controlled group), students who will undergo traditional instructions. To establish a baseline for comparison in this study, both the experimental and control groups will undergo a pre-test measuring their initial understanding of orthographic and isometric projection.

2.3 Research Instruments

The tool employed to assess student performance in both the pre-test and post-test is based on the Purdue Spatial Visualization Test: Rotations (PSVT: R). The researcher adapted this standardized test, and this is a widely used assessment tool in engineering education to measure students' spatial reasoning skills, particularly their ability to mentally rotate objects. Originally a part of the broader Purdue Spatial Visualization Tests (PSVT) developed by Guay (1976), the PSVT: R improved into an independent, extended version (Yoon, 2011) focusing specifically on mental rotation (Maeda et al., 2013).

Accordingly, the PSVT: R will serve as the primary quantitative instrument in this study. Providing data on students' spatial abilities before and after intervention, this will be one of the tools to analyze the potential of Spatial Vis and its impact in improving the students' performance in orthographic and isometric lessons.

2.4 Data Gathering Procedure

The data gathering procedure will involve this process beginning with obtaining necessary ethical approvals. Additionally, a permission form that is approved and the informed consent of the student participants as well as their parents or guardians. Students took pre-tests using PSVT: R (Yoon, 2011) a standardized test before navigating Spatial Vis application.

In the implementation phase, the experimental group will receive training using Spatial Vis in their respective mobile or desktop platforms, integrating in the lesson with the same content but practiced in different platforms. While the control group receives traditional instruction on the same concepts. Throughout the intervention, student motivation and engagement will be assessed through interviews and observations throughout the three groups.

To gauge improvements in spatial reasoning skills, the PSVT: R spatial thinking test, which was given during the pre-test phase, will be administered again. Every group will finish the assignments and exercises using desktop, mobile, and traditional methods. To ensure ethical practice, the study adhered to guidelines in effect at the time, specifically upholding participant confidentiality, voluntary participation, and data protection.

2.5 Data Analysis

The Mean, Standard Deviation (SD), Standard Error of the Mean (SE), and Coefficient of Variation (CV) were calculated. This calculation was performed separately for each of the three groups (two experimental and one control) at both the pre-test and post-test measurement points.

- Paired samples t-tests were used to compare the pre-test and post-test scores for each group. This analysis was conducted to evaluate the impact of the instructional method on spatial visualization skills within each group (Talikan et al., 2024).

- A One-Way Analysis of Variance (ANOVA) was performed. Given that the study comprised three independent groups of respondents (two experimental and one control), this test was utilized to determine if statistically significant differences existed among the post-test group means (Mouritsen et al., 2016).

3. Results and Discussion

This section presents the statistical findings from the quantitative analysis of the Purdue Spatial Visualization Test: Rotations (PSVT: R) to determine the effectiveness of the Spatial Vis application.

Table 1: Descriptives

Cases	N	Mean	SD	SE	COV
Traditional	17	2.588	4.331	1.050	1.673
Mobile	14	3.786	4.264	1.140	1.126
Desktop	14	2.000	4.038	1.079	2.019

The results and discussion are structured into three main parts: (1) Descriptive statistics for pre-test and post-test scores across the Control (Traditional) and Experimental (Mobile and Desktop) Groups; (2) Analysis of learning gains within each of the three groups; and (3) Comparison of post-test performance between the groups using Analysis of Variance

(ANOVA) to establish significant differences due to the intervention method. These empirical results are subsequently discussed in relation to existing literature on technology-mediated instruction and spatial skills.

The descriptive table on Spatial Vis shows differences among the three learning groups: Traditional, Mobile App, and Desktop. The Traditional group

(N = 17) obtained a mean score of 2.588 with a standard deviation of 4.331 and a standard error of 1.050, resulting in a coefficient of variation of 1.673, indicating moderate improvement with some variability among participants. The Mobile App group (N = 14) achieved the highest mean score of 3.786, with a standard deviation of 4.264, a standard error of 1.140, and a lower coefficient of variation 1.126 compared to the other groups, suggesting more consistent performance and greater improvement in spatial visualization. Meanwhile, the Desktop group

(N = 14) recorded the lowest mean score of 2.000, a standard deviation of 4.038, a standard error of 1.079, and the highest coefficient of variation 2.019, reflecting higher variability in performance and less overall improvement. Overall, these results indicate that participants who used the Mobile App showed better and more consistent spatial visualization ability compared to those in the Traditional and Desktop groups.

Paired samples t-tests were used to compare pre-test and post-test scores for each group to evaluate the impact of different instructional methods on spatial visualization skills.

Table 2: Pre-test & Post-test T-test Analysis for Traditional Instruction without Spatial Vis

<i>Paired Samples T-Test</i>				
Measure 1	Measure 2	t	df	p
Pre (control)	- Post (control)	-2.464	16	0.025

Table 2 presents the results of a paired samples t-test conducted to evaluate the effect of traditional instruction without spatial visualization training on student performance, comparing pre-test and post-test scores within a control group.

The t-test statistics (t) is reported as -2.464, with 16 degrees of freedom (df), and a p-value of 0.025. This statistical test assesses whether the mean difference between two sets of scores—pre-test and post-test for the same participants—is significantly different from zero.

Because the p-value (0.025) is less than 0.05, the result is statistically significant. This indicates that there was a meaningful difference in performance between the pre- and post-test scores of students who received only traditional instruction, with no spatial visualization training. The negative t-value suggests that post-test scores were lower than pre-test scores, or at least did not improve significantly, implying that traditional instruction alone may not have positively impacted student performance in this context.

Table 3: Pre-test and Post-test T-test Analysis for Spatial Vis using the Mobile App

<i>Paired Samples T-Test</i>				
Measure 1	Measure 2	t	df	p
Pre (mob)	- Post (mob)	-3.322	13	0.006

Table 3 presents the results of a paired samples t-test that evaluated the impact of a mobile application on users' spatial visualization skills. Specifically, it compares participants' scores before (Pre) and after (Post) using the app, labeled here as "Pre (mob)" and "Post (mob)."

These values indicate that the difference between pre- and post-test scores is statistically significant with a p-value well below the conventional threshold of 0.0006 (Majumder & Maheshwarappa, 2023).

The negative t-value suggests that scores improved from pre-test to post-test, assuming higher scores represent better performance. With 13 degrees of freedom, it's clear the test was conducted with data from 14 participants

(since $df = n - 1$ for a paired t-test). In summary, this analysis shows that the mobile app had a statistically significant positive effect on participants' spatial visualization abilities.

Table 4: Pre-test and Post-test T-test Analysis for Spatial Vis using the Desktop

<i>Paired Samples T-Test</i>					
Measure 1		Measure 2	t	df	p
Pre (desk)	-	Post (desk)	-1.853	13	0.087

Table 4 presents the results of a paired samples t-test comparing participants' spatial visualization performance before and after using a desktop version of a tool or application. As with the previous analysis, this test evaluates whether there is a statistically significant difference in scores following the intervention.

Although the negative t-value suggests an improvement from pre-test to post-test, the p-value of 0.087 exceeds the conventional threshold of 0.05, indicating that the improvement is not statistically significant. While there appears to be a trend toward better scores after the desktop intervention, the evidence isn't strong enough to confidently conclude that the desktop app significantly enhanced spatial visualization skills in this sample.

Overall, while the desktop version shows potentially positive but inconclusive effects, it contrasts with the mobile version, which showed a statistically significant improvement in Table 3.

The significant improvement observed across both experimental groups validates the core of this study: that spatial visualization ability is malleable and capable of improvement through targeted practice (Uttal et al., 2012). This finding corroborates the broader literature confirming that a structured intervention focused on sketching and mental manipulation leads to measurable gains (Delson et al., 2015). The gains confirm that the content delivered in the intervention phase activated the spatial reasoning skills measured by the PSVT: R (Yoon, 2011).

Table 5: ANOVA Test for variables Traditional, Mobile App, and Desktop

<i>ANOVA – Gain</i>					
Cases	Sum of Squares	df	Mean Square	F	p
Spatial Vis	23.303	2	11.651	0.654	0.025
Residuals	748.475	42	17.821		

Table 5 presents the results of a one-way Analysis of Variance (ANOVA) conducted to determine whether there are significant differences in spatial visualization gains among three groups using different instructional methods: traditional, mobile app, and desktop.

The dependent variable here is gain (scores) in spatial visualization ability, while the independent variable is the mode of instruction (three levels: traditional, mobile, and desktop). These results indicate that there is no statistically significant difference between the three instructional methods in terms of their impact on spatial visualization gains, as

the p-value (0.525) is well above the 0.05 threshold. The F-value (0.654) further suggests that the variability between group means is relatively small compared to the variability within groups (residuals).

While the primary between-group analysis (ANOVA) comparing the three instructional methods did not yield a statistically significant difference ($F = 0.654$, $p = 0.525$) the descriptive statistics revealed a consistent trend for the Mobile App group, which achieved the highest mean gain score

($M = 3.876$) across all conditions. Furthermore, within-group analysis confirmed a statistically significant improvement from pre-test to post-test for the mobile application method ($t = -3.322$, $p = 0.006$). The study's limited ability to confirm the observed differences was likely due to low statistical power, which itself stemmed from the small and uneven sizes of the instructional groups. Consequently, these findings strongly suggest the practical superiority of the Mobile App method for enhancing spatial visualization, and future research with a larger sample is warranted to statistically validate the promising descriptive data observed.

The observed descriptive superiority of the Mobile App group aligns with findings from other studies exploring the utility of the Spatial Vis application. For instance, Rogers et al. (2024) reported that 70% of their 45 participants who utilized the application showed improvement, translating to a 6.3% increase in the mean PSVT: R score. However, a key difference distinguishes the current study: the Rogers et al. (2024) study was not a controlled study, and its participants possessed prior engineering experience, which likely acted as a confounding factor influencing post-intervention results.

In contrast, the present study employed a quantitative analysis with three distinct instructional groups (Mobile App, Desktop, and Traditional), specifically introducing two controlled digital modes to test if the implementation environment (desktop versus mobile) made a differential impact. Despite this controlled approach, the between-group analysis and results have its own limitations.

This outcome is not unprecedented in the literature on educational technology interventions. For example, the study by Baltaci et al. (2022) on an Augmented Reality (AR) application also demonstrates limitations in the improvement of students' spatial visualization skills. Both the current study and the Baltaci et al. (2022) findings demonstrate an insight: the mere introduction of digital tools does not automatically guarantee significant gains in spatial abilities.

The common thread between these two studies is their context within specific educational settings (high school), where factors related to the student population and implementation environment can influence outcomes. Despite the lack of significant skill gains in the quantitative data, students in the Baltaci et al. (2022) study reported increased excitement, curiosity, and overall positive affective attitudes towards using the AR learning material. This motivational impact mirrors the observation in the current study that students demonstrated high levels of engagement and expressed significant interest in the Mobile Spatial Vis application. This suggests a crucial point of practical efficacy: the value of digital tools may first manifest through enhanced motivation and positive user experience rather than immediate, measurable skill acquisition. This initial engagement could be the underlying mechanism that drives the superior descriptive performance of the Mobile App group, warranting focused investigation in future research.

4. Conclusion

This study evaluated the potential of integrating Spatial Vis into technical education by comparing gains across traditional, mobile, and desktop instructional modalities. The intervention spanned a total of two weeks, covering the content of Working Drawings and Signs and Symbols. In the MATATAG Curriculum of the Department of Education, Cahapay (2020) mentioned that curriculum unpacking is the vital process of translating the intended academic program into classroom instruction. This step is necessary to ensure the curriculum's desired learning goals are effectively linked to and realized through actual teaching practices. That is why the students understand complex working drawings, the researcher incorporated and implemented this application, Spatial Vis to scaffold their learning towards the complexity of working drawings.

The quantitative analysis of the PSVT: R scores yield a significant finding: students utilizing Spatial Vis on mobile devices has seen an improvement in spatial visualization skills. These observed gains were statistically elevated to those recorded by both the control (traditional instruction) and the desktop experimental groups, validating the mobile intervention as the effective delivery platform. This empirical evidence underscores the potential of accessible mobile educational technology to serve as a potent pedagogical tool for improving technical competencies related to orthographic and isometric projection.

The findings underscore the significant potential of the Mobile Spatial Vis application as an innovative and scalable pedagogical tool. Its capacity to facilitate substantial learning gains, while simultaneously providing students with the flexibility to engage in spatial visualization tasks independently and in personal comfortable settings, makes it an invaluable asset for modern educational contexts.

Based on these findings and limitations, future research should focus on optimizing the intervention and deepening the theoretical understanding of the platform differences. (1) Integrate Spatial Vis as a Supplement: The Spatial Vis application is recommended as engaging and effective tool for teaching 'Working Drawings' competency in the TLE curriculum, especially for promoting persistence and giving immediate, personalized feedback that teachers often cannot provide in large classrooms. (2) Conducting controlled longitudinal studies with larger, randomized samples to confirm the durability of the learning gains over time; (3) Investigating the role of prior knowledge of learners' spatial ability as a covariate to better isolate the application's unique effect; (4) Developing and rigorously testing offline functionality within the application to eliminate reliance on unstable internet access in geographically challenging areas; and (5) Exploring the necessity and efficacy of standardized teacher training to maximize the integration potential of spatial reasoning technologies.

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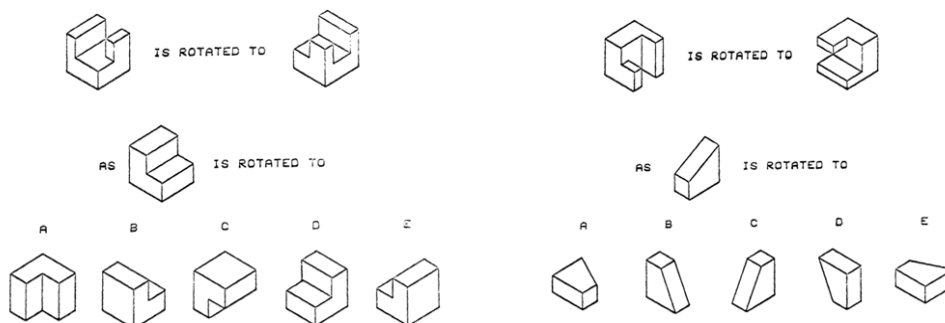
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Appendix A

Purdue Spatial Visualization Test: Rotations (PSVT: R) PRE-TEST & POST-TEST

Name: _____

This test consists of 30 questions designed to see how well you can visualize the rotation of three-dimensional objects. Shown below is an example of the type of question included in this test.

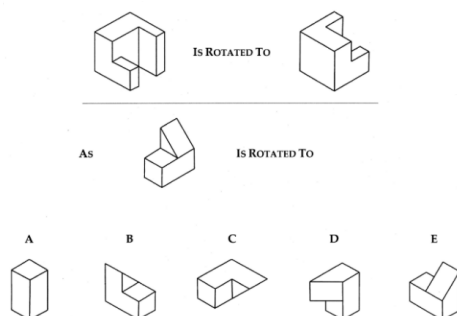


Instructions: You are to:

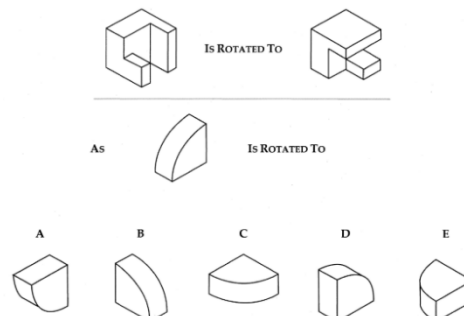
1. Study how the object in the top line of the question is rotated;
2. Picture in your mind what the object shown in the middle line of the question looks like when rotated in the same manner.
3. Encircle from among the five drawings (A, B, C, D, or E) given in the bottom line of the question the one that looks like the object rotated in the correct position.

Test Proper:

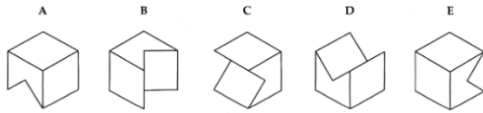
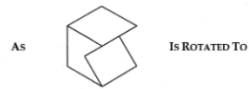
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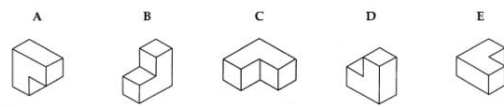
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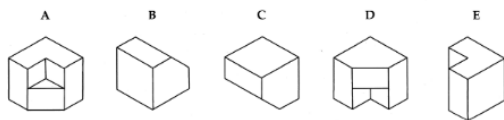
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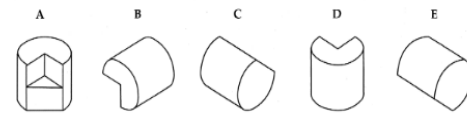
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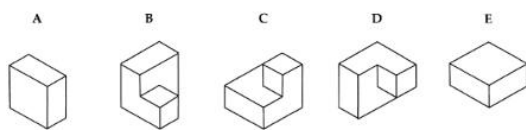
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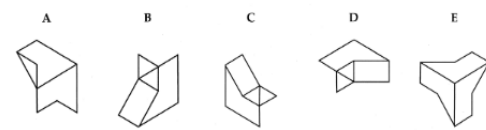
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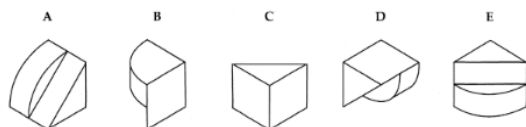
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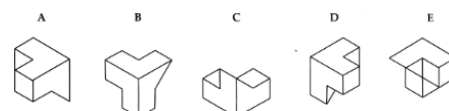
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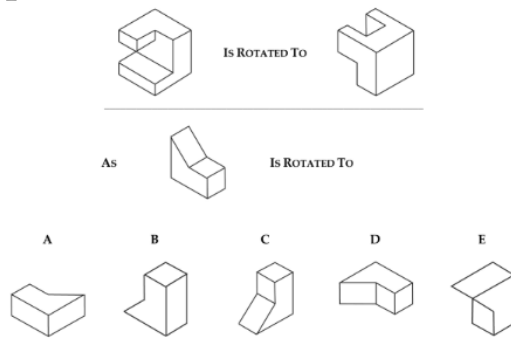
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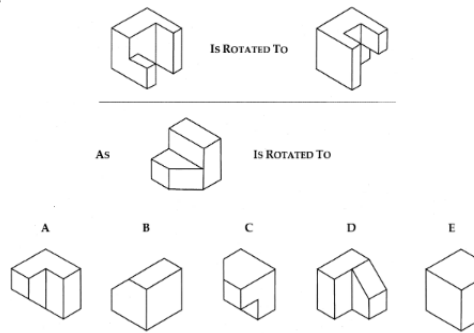
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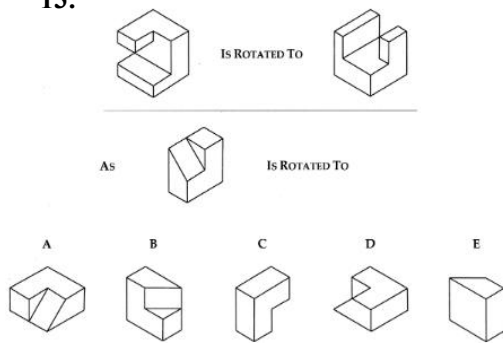
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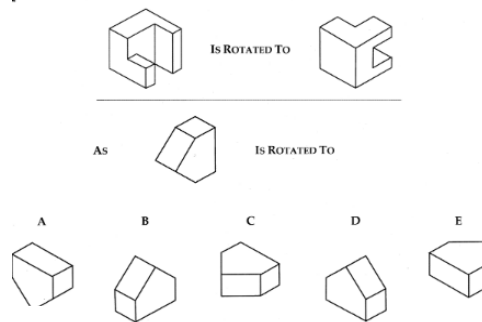
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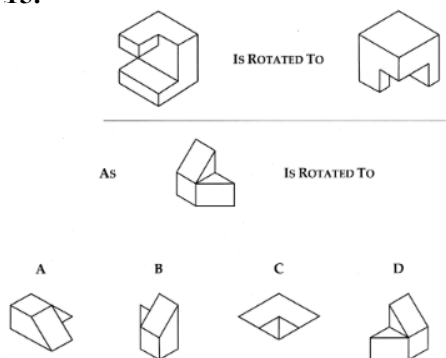
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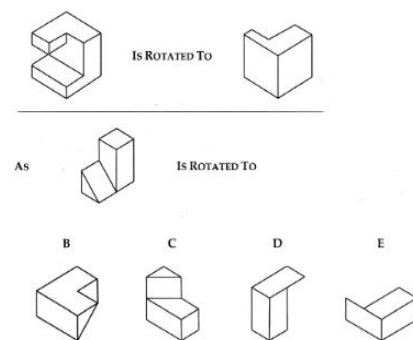
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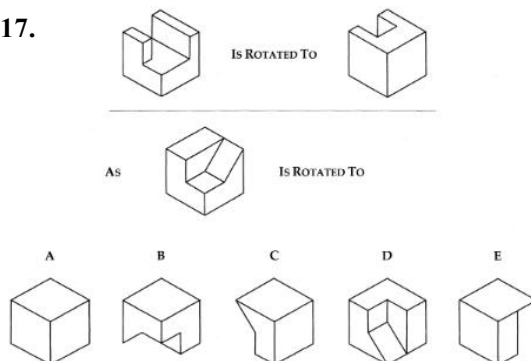
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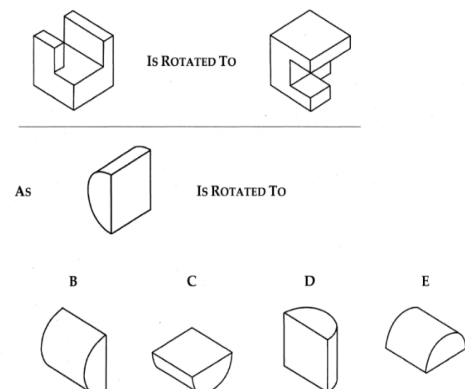
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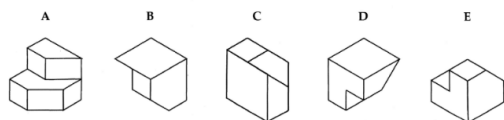
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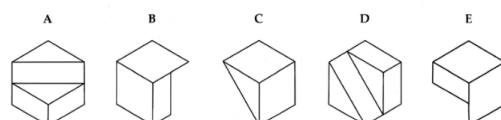
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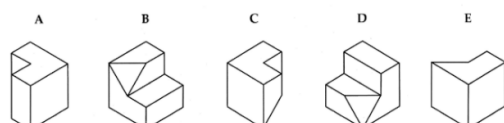
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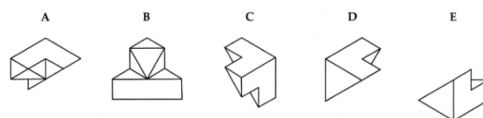
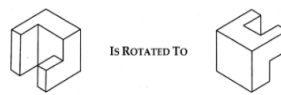
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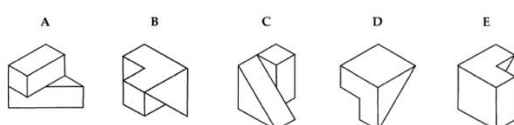
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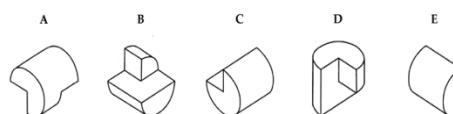
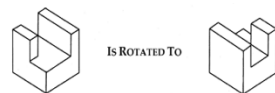
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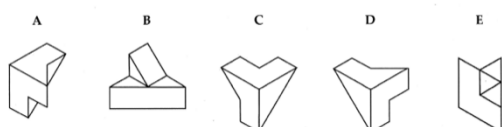
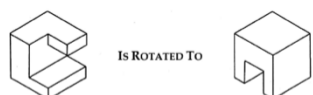
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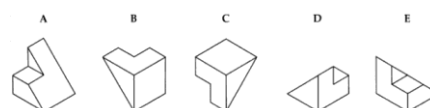
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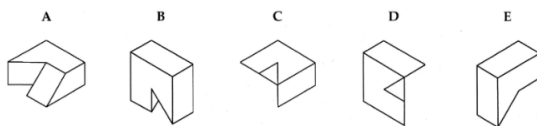
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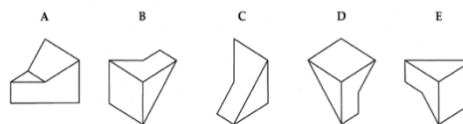
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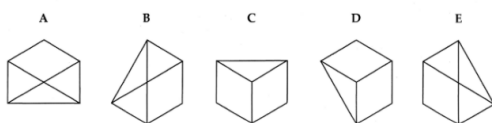
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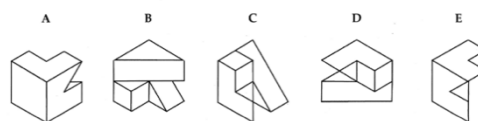
28.



29.



30.



Revised PSVT:R (2011)

Answer Key

1.	B	11.	E	21.	A
2.	A	12.	E	22.	D
3.	A	13.	B	23.	D
4.	D	14.	D	24.	C
5.	B	15.	C	25.	D
6.	C	16.	E	26.	C
7.	E	17.	A	27.	B
8.	E	18.	A	28.	E
9.	E	19.	B	29.	C
10.	D	20.	B	30.	E