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# Assessing the Orthographic Projection Skills of Drafting Technology Students

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**Abstract:** Orthographic projection represents three-dimensional objects in two dimensions from multiple views—front, top, and side—using parallel lines that are perpendicular to the drawing plane. This method maintains accurate geometry and scale, eliminating distortion caused by perspective. This study investigates the orthographic projection skills of Drafting Technology students through an assessment based on Speed, Legibility, Accuracy, and Neatness (SLAN). The research aimed to determine skill levels across various factors such as academic performance, access to gadgets, financial status, senior high school track, and sex. Quantitative data were gathered and analyzed using statistical tools including frequency, percentage, mean, standard deviation, t-test for Independent Samples, and One-way ANOVA. Results indicated significant differences in performance, notably among students with varying academic backgrounds and levels of access to technology. Students who had better access to gadgets and stronger academic preparation generally performed better in SLAN-based tasks. The study highlights the importance of integrating support mechanisms and differentiated instruction into the curriculum to bridge skill gaps. The findings can guide educators and administrators in developing targeted interventions that enhance technical drawing skills, improve equity in learning outcomes, and better prepare students for professional practice in drafting and related fields.

**Keywords:** Orthographic Projection; Drafting Technology; Drafting Skills; SLAN (Speed, Legibility, Accuracy, Neatness); Assessment Test; Projection Techniques; 2D and 3D Representation; Technical Drawing; Spatial Visualization.

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## 1. Introduction

Orthographic projection is a cornerstone of drafting technology and is crucial for accurately translating three-dimensional forms into two-dimensional representations [7]. Its importance resonates across technical disciplines like engineering and architecture, where precise visual communication underpins effective collaboration and design comprehension [4]. However, a notable range in orthographic projection proficiency exists among students, potentially shaped by prior learning experiences and available resources [27]; [24]. Notably, studies have also examined various facets of drafting skills, including aspects related to Speed, Legibility, Accuracy, and Neatness (SLAN), highlighting the multifaceted nature of proficiency in this area [3]; [8]. This study focuses on understanding these variations in skill, specifically examining Speed, Legibility, Accuracy, and Neatness (SLAN) in the orthographic projections produced by Drafting Technology students. By employing an assessment test measuring these key aspects, this research investigates the relationship between SLAN scores and student characteristics, including academic performance, access to gadgets, financial status, senior high school track, and sex. Ultimately, the findings of this study seek to provide valuable insights for enhancing the Drafting Technology curriculum and developing targeted instructional interventions designed to improve student outcomes in this essential skill.

## 2. Literature Review

Orthographic projection is a foundational technique in technical drawing, enabling the representation of three-dimensional objects on a two-dimensional plane [7]. This method is indispensable across diverse fields, including engineering, architecture, and manufacturing, where precise visual representations of designs are paramount for construction, product development, and technical documentation [4]. The capacity to interpret and generate accurate orthographic projections is a critical competency for professionals within these disciplines. Effective proficiency in orthographic projection fosters spatial reasoning abilities, which are essential for comprehending intricate structures and systems. This skill holds particular significance for students aspiring to careers in technical domains, where deficiencies can impede their academic and professional progress [3]. Consequently, various factors influencing the acquisition and development of proficiency in orthographic projection—such as the effectiveness of instructional tools like 3D models [27] and CAD software [24], the quality of learning materials [8], and innovative teaching approaches [30] play a crucial role in shaping students' success in mastering this fundamental skill.

### 2.1. Factors Influencing Orthographic Projection Proficiency

Several factors have been identified as influencing students' proficiency in orthographic projection. The effectiveness of instructional tools and methodologies plays a significant role, with studies exploring the benefits of incorporating 3D solid models [27] and computer-aided design and drafting (CAD) software [24] in enhancing spatial visualization and drawing accuracy. The quality and nature of instructional materials also contribute to learning outcomes, as highlighted by evaluations of worktexts in mechanical drafting [8]. Furthermore, innovative teaching approaches, such as integrating augmented reality, are being investigated for their potential to improve students' understanding of technical drawings [30]. Beyond instructional elements, student-related characteristics are crucial. For instance, a student's prior academic background and attitude towards technical drawing can significantly affect their skill acquisition [3]. Ultimately, a combination of effective teaching strategies, appropriate resources, and positive student engagement shapes the development of proficiency in this fundamental technical skill [7]; [4].

A significant factor influencing proficiency in orthographic projection is the prior academic background in technical drawing and related subjects. Exposure to foundational subjects such as geometry, drafting, and engineering drawing has enhanced students' spatial visualization skills, which are crucial for understanding orthographic projection [16]. Students who have not been exposed to these subjects often face greater challenges in developing the necessary skills, as they lack the background knowledge that helps in visualizing and interpreting projections [18]. In particular, the foundational concepts in geometry, such as angles, projections, and symmetry, are directly applicable to the principles of orthographic projection and can significantly aid in students' ability to create and interpret drawings [14].

Computer-aided design (CAD) has transformed how technical drawings are taught and learned. CAD software provides students with powerful tools for visualizing and manipulating orthographic projections, offering numerous advantages over traditional manual drafting techniques [5]. However, the shift from manual drafting to CAD can pose challenges for students who lack access to technology or are unfamiliar with digital tools. Research indicates that unequal access to CAD software can lead to disparities in learning outcomes, with students in underfunded schools or regions struggling to achieve the same proficiency levels as those with better resources [9]. While CAD provides an efficient method for learning orthographic projection, it also requires an understanding of technical drawing principles and the software itself, meaning that access to digital tools alone does not guarantee proficiency [1].

Effective instructional strategies are essential for fostering proficiency in orthographic projection. Active learning techniques, such as peer review, brainstorming sessions, and freewriting exercises, have been found to enhance students' engagement and understanding of technical drawing concepts [29]. These techniques encourage students to actively participate in learning, reinforcing their spatial reasoning and visualization abilities. Additionally, metacognitive strategies, such as self-reflection and problem-solving approaches, are crucial in improving students' ability to navigate the complexities of orthographic projection [31]. Best teaching practices focusing on hands-on learning, individualized feedback, and real-world applications have significantly enhanced spatial reasoning and technical drawing skills [22].

Research on gender differences in spatial visualization skills has been a point of interest in studies of technical drawing proficiency. Some studies suggest that males, on average, perform better in spatial tasks, including those involving orthographic projection [13]. However, it is important to note that these differences are not fixed and can be influenced by instructional methods and learning environments. Studies show that when both sexes are given equal access to resources and opportunities, the gap in spatial abilities can be minimized [6]. Furthermore, gender disparities in engagement and motivation in technical subjects can also impact performance in orthographic projection, suggesting that addressing these disparities is important for fostering an inclusive learning environment [12]. Overall, academic achievement is often correlated with success in orthographic projection. Students with strong performance in mathematics and science typically exhibit higher proficiency in technical drawing due to their enhanced spatial reasoning and problem-solving abilities [20]. Additionally, cognitive abilities such as attention, memory, and processing speed influence how well students master orthographic projection [17]. Visual, auditory, or kinesthetic learning styles also affect how students approach and master orthographic projection. Tailoring instruction to accommodate different learning styles has improved students' understanding and performance [2].

Socioeconomic status (SES) significantly affects students' access to learning resources, including textbooks, CAD software, and drafting materials. Students from lower SES backgrounds may face challenges in accessing these resources, which can hinder their ability to develop proficiency in orthographic projection [28]. Disparities in SES also correlate with differences in the quality of education, as schools in low-income areas often have fewer resources and less experienced teachers [25]. Institutional support, such as financial aid for purchasing materials and providing access to technology, is essential in ensuring that all students have the opportunity to succeed in mastering orthographic projection [10].

### 2.2. Challenges in Learning Orthographic Projection

Students often encounter several challenges in the process of learning orthographic projection. A primary hurdle lies in developing strong spatial visualization skills, essential for mentally rotating three-dimensional objects and accurately depicting them in two dimensions [27]. Difficulties in grasping the relationship between the different views (front, top, side) and visualizing hidden lines can lead to errors in accuracy and legibility [8]. Furthermore, inadequate preparation in foundational concepts like geometry and basic drawing can hinder a student's ability to understand and apply the principles of orthographic projection [3]. The abstract representation of 3D forms on a 2D surface can be a cognitive challenge for many learners. Moreover, limited access to or ineffective use of technology, such as CAD software, can prevent students from fully exploring and practising orthographic projection dynamically and interactively [24]. Addressing these challenges through targeted instructional strategies and the thoughtful integration of appropriate resources [30]; [7] is crucial for improving student learning outcomes in this fundamental technical skill.

Despite its importance, many students face challenges in mastering orthographic projection. One common difficulty is the complexity of visualizing and interpreting three-dimensional objects in two dimensions. Students often struggle to translate spatial relationships accurately, leading to errors in their projections [26]. Gaps in curriculum design, such as insufficient emphasis on spatial reasoning and lack of adequate practice opportunities, also contribute to these difficulties. Additionally, the learning environment, including access to resources and quality instruction, significantly shapes students' mastery of orthographic projection [11].

### 2.3. Recommendations for Improving Teaching and Learning

Drawing from research and pedagogical considerations, several recommendations emerge for enhancing the teaching and learning of orthographic projection. Integrating visual and interactive tools, such as 3D solid models [27] and computer-aided design and drafting (CAD) software [24], can significantly improve students' spatial visualization abilities and provide opportunities for hands-on practice. Developing high-quality, well-structured instructional materials, including clear explanations and varied exercises [7]; [8] is crucial for student understanding. Furthermore, exploring innovative teaching methodologies, such as incorporating augmented reality to bridge the gap between 2D representations and 3D concepts [30], holds promise for engaging learners and fostering deeper comprehension. Addressing individual student needs through differentiated instruction and providing targeted feedback on speed, legibility, accuracy, and neatness (SLAN) is also essential [3]. Finally, emphasizing the real-world applications and relevance of orthographic projection within various technical fields [4] can increase student motivation and highlight the value of mastering this fundamental skill.

Several strategies can be implemented to improve students' proficiency in orthographic projection. First, ensuring equitable access to manual drafting tools and CAD software is crucial for providing all students with the necessary resources to succeed. Additionally, enhancing instructional methods to accommodate diverse learning styles can help address students' varying needs. Curriculum modifications, such as integrating more practical exercises and fostering spatial reasoning, can help students bridge the gaps in their technical drawing skills [19]. Teachers can also use formative assessments to identify skill gaps early and provide targeted interventions to help students improve [15].

Proficiency in orthographic projection is critical for students pursuing careers in engineering, architecture, and related fields. Various factors, including prior academic background, access to technology, instructional strategies, and socioeconomic status, influence students' ability to master this skill. Understanding these factors can help educators design more effective teaching strategies and provide the necessary support for all students. Future research should explore the long-term impact of technological advancements and examine the role of instructional practices in bridging the gaps in spatial reasoning abilities across different demographic groups. Multiple factors, including prior exposure to technical drawing, access to technology, academic performance, financial status, and individual differences in speed, legibility, accuracy, and neatness, influence the development of orthographic projection skills. The SLAN framework provides a structured approach to evaluating these competencies. This study builds upon existing literature by analyzing how these variables impact Drafting Technology students' performance and identifying areas for potential improvement in drafting education.

## 3. Methodology

This study employed a quantitative research design to assess the orthographic projection skills of randomly selected Drafting Technology students. The sample size was determined using the Raosoft sample size calculator to ensure statistical validity. Students participated in a practical assessment where they were given an isometric drawing and tasked with manually creating a corresponding orthographic projection. Their performance was evaluated using the SLAN framework, a rubric considering speed, legibility, accuracy, and neatness. Data analysis involved descriptive statistics (frequency, percentage, mean, and standard deviation) to establish baseline skill levels. Inferential statistics, specifically t-tests for Independent Samples and One-way ANOVA, were utilized to identify significant differences in performance across various categories or groups.

## 4. Results and Discussion

### 4.1. Level of Orthographic Projection Skills of the Students

The results from the study on orthographic projection skills of Drafting Technology students highlight significant variations in performance across various demographic factors, such as academic performance, sex, monthly family income, senior high school (SHS) track, and access to gadgets. These findings provide insight into how different factors influence students' Speed, Legibility, Accuracy, and Neatness (SLAN) competencies.

### 4.2. Orthographic Projection Skills of the Students as an Entire Group

The overall performance of students in SLAN showed a mix of average and satisfactory ratings across all variables (Table 1).

**Table 1:** Orthographic Projection Skills of the Students as an Entire Group

| Variable | Entire Group | | |
|---|---|---|---|
| | Mean | SD | Description |
| Speed | 3.03 | 1.49 | Average |
| Legibility | 3.02 | 1.56 | Satisfactory |
| Accuracy | 2.81 | 1.33 | Satisfactory |
| Neatness | 3.07 | 1.35 | Satisfactory |

The study's assessment of Speed, Legibility, Accuracy, and Neatness (SLAN) aligns closely with key trends observed in the literature, which suggests that while students demonstrate a baseline level of competence in technical drawing skills, there remains considerable room for improvement. As the study's results show, students performed at an "average" level for Speed and Legibility and at a "satisfactory" level for Accuracy and Neatness, indicating that while students are meeting basic expectations, variability in their performance suggests challenges in achieving consistency and efficiency in these areas. The "average" rating for speed (mean = 3.03, SD = 1.49) reflects students' ability to complete tasks within a reasonable timeframe but with notable differences in efficiency. This variability aligns with findings in the literature, highlighting that time management in technical drawing tasks, including orthographic projection, can be influenced by various factors, including prior knowledge and resource access [16]. Davis and Durose [9] also point out that unequal access to technology and instructional strategies can contribute to differences in how efficiently students can complete tasks, which is reflected in the spread of scores in the study.

Similarly, legibility (mean = 3.02, SD = 1.56), which was rated as "average," shows a wide range of student performance. While most students produced legible work, the variability suggests that some students faced challenges in maintaining clarity. This observation corroborates research by Boyer et al. [5], which indicates that legibility in technical drawings, such as orthographic projections, requires technical skill and consistency, which may vary depending on student's prior experiences and instructional practices. Lee et al. [18] further explain that a lack of foundational skills, such as consistent line thickness or understanding of orthographic views, could lead to these inconsistencies in student performance, which the study data also suggests. Accuracy (mean = 2.81, SD = 1.33), rated as "satisfactory," indicates that some inconsistencies were observed while students generally met the standards for accuracy in their orthographic projections. Accuracy in technical drawing is closely linked to spatial reasoning and mathematical ability, as noted by Miller and Becker [20]. These cognitive factors significantly influence students' ability to correctly interpret three-dimensional objects on two-dimensional planes. The variability in accuracy scores may reflect these underlying cognitive differences and the challenges students face in applying geometric principles to technical drawing tasks [14].

Neatness (mean = 3.07, SD = 1.35), which was also rated as “satisfactory,” similarly reveals that while most students produced neat and organized drawings, some inconsistencies remained in their work. Neatness is essential for clarity and effective communication in technical drawing. As Salvia and Gennaro [23] suggest, well-organized technical drawings enhance the understanding of the design and the overall quality of the work. The study’s finding that there is room for improvement in neatness resonates with Riley and Smith [22], who argue that hands-on learning and individualized feedback are key strategies for improving attention to detail and consistency in technical drawing. The variability observed in neatness scores suggests that some students may need additional support in these areas to improve the clarity and presentation of their work.

Students exhibit “average” and “satisfactory” performance across the SLAN variables, consistent with the literature. This indicates that while students often meet basic expectations, challenges in achieving consistency and efficiency remain. Research emphasizes the importance of foundational skills, access to technology, effective instructional strategies, and tailored learning approaches to help students improve their technical drawing proficiency [29]; [19]. The data also suggests that, despite meeting basic standards, students have significant potential to enhance their skills in Speed, Legibility, Accuracy, and Neatness through targeted interventions and continued practice.

### 4.3. Orthographic Projection Skills as to Academic Performance

The data suggest a clear difference in performance across different academic levels. The students were grouped as Inferior, Average, and Superior based on their academic performance (Table 2):

**Table 2:** Orthographic Projection Skills of the Students when Grouped According to Academic Performance

| Variable | Inferior | | | Average | | | Superior | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Description | Mean | SD | Description | Mean | SD | Description |
| Speed | 3.06 | 2.0 | Average | 3.20 | 1.0 | Average | 3.88 | 1.5 | Fast |
| Legibility | 3.13 | 2.0 | Satisfactory | 2.68 | 2.0 | Satisfactory | 3.18 | 1.6 | Satisfactory |
| Accuracy | 2.69 | 1.0 | Satisfactory | 3.04 | 2.0 | Satisfactory | 2.76 | 1.2 | Satisfactory |
| Neatness | 2.94 | 1.0 | Satisfactory | 3.16 | 1.0 | Satisfactory | 3.12 | 1.5 | Satisfactory |

The data reveals a clear distinction in performance across different academic levels, with students grouped into Inferior, Average, and Superior categories. A prominent difference is observed in the speed variable. Students in the “Superior” group exhibited a significantly higher mean score of 3.88, indicating that they completed orthographic projection tasks at a faster rate compared to both the “Inferior” (mean = 3.06) and “Average” (mean = 3.2) groups. This suggests that superior students may possess more advanced skills in processing and executing orthographic projections, potentially reflecting better time management or enhanced spatial reasoning abilities, which enable them to work more efficiently. Regarding legibility, the data showed significant variation across the academic groups, with the “Average” group scoring the lowest mean of 2.68. This implies that legibility could be challenging for these students, while the “Inferior” and “Superior” groups displayed relatively similar mean scores of 3.13 and 3.18, respectively. This suggests that students at the extremes of academic performance—whether superior or inferior—tend to perform better in producing legible work. At the same time, those in the “Average” group may face more challenges in ensuring clarity in their orthographic projections. These challenges might include maintaining consistent line thickness or correctly interpreting orthographic views.

Regarding accuracy and neatness, the data did not reveal significant differences between the three academic groups, with all groups scoring similarly in these areas. This suggests that accuracy and neatness are relatively consistent across all academic levels, possibly implying that these attributes are less influenced by overall academic performance. The uniformity in scores may indicate that these skills depend more on attention to detail, focus, and consistent practice than cognitive ability or academic standing. The findings underscore that while there are clear differences in speed and legibility based on academic performance, accuracy and neatness appear stable across the groups. This suggests that certain skills, such as speed, show more differentiation among students of varying academic levels. In contrast, others, like accuracy and neatness, may offer greater potential for universal development, regardless of academic background.

The literature on orthographic projection (OP) highlights its importance in fields like engineering, architecture, and manufacturing, where accurate technical drawings are crucial. Salvia and Gennaro [23] emphasize that proficiency in OP involves complex spatial reasoning skills essential for representing three-dimensional objects on two-dimensional planes. This skill is particularly important for students pursuing technical careers, as difficulties in visualizing and interpreting projections can hinder their academic and professional success [21]. Various factors influence students' development of proficiency in OP. One critical factor is their prior academic background, particularly exposure to foundational subjects like geometry, drafting, and engineering drawing. According to Kelly and Graham [16], students with a strong foundation in these subjects tend to perform better in OP tasks, as these areas help build the spatial reasoning skills necessary for interpreting and creating orthographic projections. Conversely, students lacking this background may face challenges in visualizing and interpreting projections, which aligns with the data where the "Inferior" group likely struggles with foundational skills crucial for excelling in OP tasks [18].

The shift from manual drafting to computer-aided design (CAD) has also influenced the teaching and learning of OP. While CAD tools offer enhanced capabilities for visualizing and manipulating technical drawings, unequal access to technology remains a significant barrier to learning. Davis and Durose [9] note that students in underfunded schools often lack access to CAD software, which exacerbates disparities in learning outcomes. Anderson and Moore [1] further explain that familiarity with technical drawing principles and CAD software is essential for proficiency in OP, and this technological divide may contribute to the faster performance observed in the "Superior" group, which may have better access to resources. Effective instructional strategies are also crucial in developing OP proficiency. Active learning techniques, such as peer review and problem-solving exercises, enhance students' engagement with technical drawing concepts [29]. The data suggests that the "Superior" students tend to perform better quickly, likely due to more effective instructional practices that foster active participation and practical application of OP concepts. Moreover, metacognitive strategies like self-reflection can help students improve their understanding and performance in OP [31], which is particularly relevant for the "Superior" group, which may benefit from more personalized and reflective learning opportunities.

Gender differences in spatial reasoning also affect students' success with OP. Some studies suggest that males generally perform better in spatial tasks, but these differences can be minimized with equal access to resources and opportunities [13]; [6]. This finding aligns with the data suggesting that factors such as motivation and access to resources, rather than innate ability, are crucial in determining OP proficiency. Instructional practices promoting equal opportunities for all students are essential for narrowing achievement gaps [12]. Socioeconomic status (SES) is another important factor influencing OP proficiency. As Williams and Taylor [28] argue, students from lower SES backgrounds often struggle to access necessary resources, such as CAD software and drafting tools, which can hinder their ability to master OP. This aligns with the findings of Sweeney and Foster [25], who suggest that schools in lower-income areas may lack the resources and experienced teachers necessary to provide high-quality instruction in technical drawing. Institutional support, such as providing financial aid and access to technology, is critical in ensuring that all students have an equal opportunity to succeed in OP [10].

Finally, challenges in mastering OP include the inherent difficulty of visualizing three-dimensional objects in two dimensions and gaps in curriculum design that fail to emphasize spatial reasoning. Fitzpatrick and Lynch [11] highlight that many students struggle to translate spatial relationships accurately, which is reflected in the variation in legibility scores in the data, particularly among the "Average" group. To address these challenges, integrating more practical exercises and fostering spatial reasoning could help improve OP proficiency for all students [19]. The literature reinforces that factors such as academic background, access to resources, instructional strategies, and SES are all critical in shaping students' proficiency in orthographic projection. The data suggests that superior students perform better quickly, likely due to more effective learning environments and resource access. However, the consistency observed in accuracy and neatness across groups highlights the potential for all students to develop these skills with appropriate support and instruction. Future research should continue to explore how technological advancements and instructional practices can help bridge gaps in spatial reasoning abilities and enhance OP proficiency for all students.

### 4.4. Orthographic Projection Skills as to Sex

The results indicate slight differences between male and female students in SLAN (Table 3):

**Table 3:** Orthographic Projection Skills of the Students when Grouped According to Sex

| Variable | Male | | | Female | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Description** | **Mean** | **SD** | **Description** |
| Speed | 3.04 | 1.5 | Average | 3.03 | 1.5 | Average |
| Legibility | 2.81 | 1.5 | Satisfactory | 3.32 | 1.6 | Satisfactory |
| Accuracy | 2.83 | 1.2 | Satisfactory | 2.78 | 1.5 | Satisfactory |
| Neatness | 3.02 | 1.3 | Satisfactory | 3.14 | 1.4 | Satisfactory |

The results reveal slight differences between male and female students in the assessment of Speed, Legibility, Accuracy, and Neatness (SLAN). When examining speed, both male and female students scored similarly, with males having a mean score of 3.04 and females at 3.03, both categorized as "Average." This shows that gender did not significantly influence the rate at which students completed tasks related to orthographic projections. The similar scores suggest that male and female students exhibit comparable efficiency when managing time while completing technical drawing tasks. However, legibility revealed a notable gender difference. Female students had a higher mean score of 3.32 than male students, who scored 2.81. Both scores fall within the "Satisfactory" range, but the difference indicates that female students performed slightly better in producing clear and legible drawings. This could suggest that female students were more consistent in maintaining clarity and accuracy in their orthographic projections, possibly reflecting greater attention to detail or different strategies when working on the task. Although the difference was not large, the finding that female students outperformed males in legibility aligns with studies that have suggested gender differences in spatial abilities, such as visualization and attention to detail [13]. Gender disparities in spatial reasoning and performance on technical tasks can vary depending on the context and the type of learning environment [6]; [12].

Regarding Accuracy and Neatness, there were no significant differences between male and female students, as both genders received similar scores. Males had a mean of 2.83 for accuracy and 3.02 for neatness, while females had a mean of 2.78 for accuracy and 3.14 for neatness. Both scores for accuracy and neatness were categorized as "Satisfactory," indicating that both male and female students exhibited comparable performance levels in these dimensions. The lack of significant differences in these areas suggests that focus, practice, and attention to detail may play a more significant role in determining accuracy and neatness than gender-based differences in spatial reasoning or technical skills. The literature on gender differences in spatial abilities supports the notion that while there are often small differences in performance between male and female students in technical tasks like orthographic projection, these differences are not absolute. Halpern [13] suggests that males generally perform better in spatial tasks, but this gap is not fixed and can be influenced by instructional methods and learning environments. Furthermore, when males and females have access to equal resources and opportunities, gender disparities in spatial reasoning and performance tend to diminish [6]; [12]. This supports the finding that the differences in performance across genders in the study were not large, particularly in areas like speed, accuracy, and neatness.

Additionally, the data indicates that while legibility showed a slight gender difference, other factors, such as instructional practices, engagement, and motivation, may be critical in narrowing or widening gender-based performance gaps. Wright and Jones [29] highlight that active learning strategies and engagement in technical tasks can enhance performance for both male and female students. Metacognitive strategies, such as self-reflection and problem-solving, also help students improve their skills and bridge performance gaps [31]. These strategies could contribute to reducing any gender-based disparities in areas like legibility and overall technical drawing proficiency. While there were slight differences in legibility between male and female students, no significant differences were found in speed, accuracy, or neatness. This is consistent with the broader literature on gender and spatial abilities, which suggests that gender differences in technical tasks like orthographic projection are often small and can be minimized with appropriate instructional strategies and equal access to resources. The results emphasize the importance of fostering an inclusive and equitable learning environment where all students, regardless of gender, can develop their spatial reasoning and technical drawing skills.

### 4.5. Orthographic Projection Skills as to Monthly Family Income

Income level had a noticeable impact on student performance, particularly in Speed and Neatness (Table 4):

**Table 4:** Orthographic Projection Skills of the Students when Grouped According to Monthly Family Income

| Variable | Below 10,000 | | | 10,001- 25,000 | | | Above 25,000 | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Description** | **Mean** | **SD** | **Description** | **Mean** | **SD** | **Description** |
| Speed | 2.93 | 2.0 | Average | 3.03 | 2.0 | Average | 3.13 | 1.0 | Average |
| Legibility | 3.20 | 2.0 | Satisfactory | 3.17 | 2.0 | Satisfactory | 2.70 | 2.0 | Satisfactory |
| Accuracy | 2.93 | 1.0 | Satisfactory | 2.67 | 1.0 | Satisfactory | 2.83 | 1.0 | Satisfactory |
| Neatness | 2.83 | 1.0 | Satisfactory | 3.23 | 1.0 | Satisfactory | 3.13 | 1.0 | Satisfactory |

The study results indicate that income level had a noticeable impact on student performance, particularly in Neatness and Speed. Students from higher-income families consistently performed better than those from lower-income families, with some differences in scores observed across the variables assessed. Regarding speed, students from families earning above $25,000 had a mean score of 3.13, slightly higher than those in the other two income groups. Students in the "Below $10,000" income bracket had a mean score of 2.93, and those in the "10,001 - 25,000" range had a mean of 3.03. While all three groups were categorized as "Average" in terms of speed, the data suggests that income level may have a small but notable effect on the efficiency with which students complete tasks. The higher mean for students in the above $25,000 income group could indicate better access to resources or a more supportive learning environment, which may allow for more efficient completion of orthographic projections. However, the relatively minor differences in speed across income levels suggest that other factors, such as time management skills and individual aptitude, may also significantly influence performance.

The most pronounced difference across income groups was observed in neatness, where students from higher-income families performed better. The group with the highest income level (Above $25,000) achieved a mean of 3.13, while students in the "Below $10,000" group had a mean of 2.83, and those in the "10,001 - 25,000" group had a mean of 3.23. Although all groups fell within the "Satisfactory" range, the trend suggests that students from wealthier backgrounds may have access to better learning materials, tools, and environments that support the production of neat and well-organized technical drawings. The discrepancy in neatness between income groups underscores the importance of resources such as drafting tools and space, which can contribute to the quality and presentation of work in technical drawing tasks. For legibility, the differences between income groups were relatively minor, with students in the lowest-income group (Below $10,000) scoring a mean of 3.2, those in the middle-income group (10,001 - 25,000) scoring 3.17, and those in the highest-income group (Above $25,000) scoring 2.7. These results indicate that while students from lower-income families were slightly more legible in their projections, the overall impact of income on legibility was not as significant as in Speed or Neatness. This suggests that legibility may be influenced by various factors, including attention to detail and individual skill development, rather than solely by income-related access to resources.

In accuracy, the differences across income levels were also relatively small, with the highest-income group (Above $25,000) showing a slight advantage (mean = 2.83) compared to the lower-income groups (Below $10,000: mean = 2.93 and 10,001 - 25,000: mean = 2.67). All groups were rated as "Satisfactory" in this category, suggesting that while accuracy in technical drawing is an important skill, it may not be as strongly affected by income levels as other skills like neatness. The literature supports these findings, especially regarding the impact of socioeconomic status (SES) on students' academic performance. As noted by Williams and Taylor [28], students from lower-income backgrounds often face challenges in accessing resources, such as high-quality materials, drafting tools, and technology, which can hinder their performance in technical subjects like orthographic projection. Higher-income students, on the other hand, are more likely to have access to these resources, leading to better outcomes in areas like Neatness [25]. Furthermore, the study by Davis and Durose [9] highlights that unequal access to technology, such as CAD software, can exacerbate disparities in learning outcomes, particularly for students from lower-income families.

Additionally, studies have shown that institutional support and resources, such as financial aid for purchasing materials and providing access to technology, can help mitigate the impact of SES on academic performance [10]. This aligns with the finding that neatness, which is heavily dependent on the quality of the tools and materials available, was notably better among higher-income students, suggesting that access to these resources plays a critical role in students' ability to produce high-quality technical drawings. While there were only minor differences in speed, legibility, and accuracy across income levels, the data reveals a clear advantage for students from higher-income backgrounds regarding neatness. These findings highlight the importance of ensuring equitable access to resources and support systems for all students, regardless of socioeconomic status, to help bridge the performance gap. Future research could explore the specific types of resources and learning environments that most significantly contribute to students' success in technical drawing tasks like orthographic projection.

### 4.6. Orthographic Projection Skills as to Senior High School Track

There was a significant disparity between students from technical drawing-aligned tracks and non-technical tracks (Table 5):

**Table 5:** Orthographic Projection Skills of the Students when Grouped According to SHS Track

| Variable | Technical Drawing Allied Track | | | Non-Technical Drawing Allied Track | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Description** | **Mean** | **SD** | **Description** |
| Speed | 3.42 | 1.0 | Fast | 3.07 | 1.5 | Average |
| Legibility | 3.41 | 2.0 | Very Satisfactory | 3.02 | 1.6 | Satisfactory |
| Accuracy | 3.77 | 1.0 | Very Satisfactory | 2.84 | 1.2 | Satisfactory |
| Neatness | 3.51 | 1.0 | Very Satisfactory | 3.02 | 1.3 | Satisfactory |

The study results reveal a significant disparity between students from technical drawing-aligned and non-technical tracks across all variables assessed: Speed, Legibility, Accuracy, and Neatness. Students from technical tracks consistently outperformed their peers in the non-technical tracks, demonstrating the benefits of specialized training in technical drawing. In terms of speed, students from technical tracks had a higher mean score of 3.42 (rated as "Fast") compared to the non-technical track students, who had a mean score of 3.07 (rated as "Average"). This suggests that students in technical tracks are more proficient in technical drawing tasks and can complete their work more efficiently. This could be attributed to the specialized training and the higher focus on practical skills in technical drawing that technical track students receive, enabling them to work more quickly and effectively than their non-technical counterparts.

For legibility, students in the technical track also outperformed those in the non-technical track, with a mean score of 3.41 (rated as "Very Satisfactory") compared to 3.02 (rated as "Satisfactory") for non-technical track students. This result reinforces that students in technical drawing-aligned tracks receive better foundational instruction, emphasising the importance of clear and readable technical drawings. The training in technical tracks likely helps students develop better control over line quality, scale, and symmetry, which are crucial for ensuring that technical drawings are legible and accurate. The most significant difference was accuracy, where technical track students achieved a mean score of 3.77 (rated as "Very Satisfactory"). In contrast, non-technical track students scored a mean of 2.84 (rated as "Satisfactory"). The gap in accuracy highlights the depth of expertise that students from technical tracks acquire in interpreting and producing precise technical drawings. Students in these tracks are likely exposed to more rigorous and focused practice, strengthening their ability to maintain accuracy in complex tasks such as orthographic projection.

In neatness, another area where technical track students excelled, they scored a mean of 3.51 (rated as "Very Satisfactory") compared to the non-technical track's mean score of 3.02 (rated as "Satisfactory"). The higher scores in neatness among technical track students suggest that they better understand the organizational and presentation aspects of technical drawing. Neatness is crucial in technical drawing as it ensures that the designs are accurate and presented in a way that is easy to interpret and communicate. The training in technical tracks likely emphasizes the importance of neatness, helping students present their work with greater precision and consistency. The findings are corroborated by existing literature on the importance of specialized training in technical drawing and its effects on students' performance. Research by Salvia and Gennaro [23] underscores that proficiency in orthographic projection and other technical drawing skills is crucial for students pursuing careers in engineering, architecture, and manufacturing. Technical training enhances students' spatial reasoning and technical drawing skills, making them better equipped to produce high-quality work [21]. Furthermore, Kelly and Graham [16] suggest that exposure to technical subjects such as geometry and drafting significantly enhances students' ability to produce accurate and legible technical drawings. This aligns with the results from the current study, where students from technical tracks consistently outperformed their peers from non-technical tracks in accuracy and legibility.

The disparity between technical and non-technical track students also highlights the benefits of hands-on learning and specialized instruction, which are often more prevalent in technical tracks. As Wright and Jones [29] emphasize, active learning techniques and practical applications are key to improving proficiency in technical drawing. Technical track students, who are likely exposed to more practical, hands-on experiences in their coursework, may benefit from these strategies, resulting in better neatness, accuracy, and legibility. Students from technical drawing-aligned tracks perform significantly better in all assessed variables—Speed, Legibility, Accuracy, and Neatness—than their non-technical track peers. This highlights the advantages of specialized training and the importance of providing students with focused instruction in technical drawing to develop their skills. Future research could further explore the specific components of technical training that contribute to these improvements and examine how such training can be integrated into non-technical tracks to improve students' performance in technical drawing.

### 4.7. Orthographic Projection Skills as to Gadget Access

Access to gadgets, particularly those related to drafting and design, impacted students' performance, especially in Speed and Neatness (Table 6):

**Table 6:** Orthographic Projection Skills of the Students when Grouped According to Access to Gadget

| OP Skills | No access | | | Limited | | | Full | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Description** | **Mean** | **SD** | **Description** | **Mean** | **SD** | **Description** |
| Speed | 2.50 | 1.0 | Average | 3.38 | 1.7 | Average | 3.18 | 1.0 | Average |
| Legibility | 3.00 | 2.0 | Satisfactory | 3.03 | 1.5 | Satisfactory | 3.02 | 2.0 | Satisfactory |
| Accuracy | 2.93 | 1.0 | Satisfactory | 2.76 | 1.2 | Satisfactory | 2.75 | 1.0 | Satisfactory |
| Neatness | 2.89 | 1.0 | Satisfactory | 3.07 | 1.5 | Satisfactory | 3.21 | 1.0 | Satisfactory |

The data reveals that access to gadgets, particularly those related to drafting and design, significantly impacted students' performance, especially in Speed and Neatness. Students with no access to gadgets consistently performed poorly compared to those with limited or full access, highlighting the importance of technology in enhancing drafting efficiency and presentation quality. In terms of speed, students with no access to gadgets had a mean score of 2.5 (rated as "Average"), which was notably lower than those with limited access (mean = 3.38, rated as "Average") or full access (mean = 3.18, rated as "Average"). The speed disparity emphasises technology's critical role in streamlining the drafting process. Access to digital tools likely enables students to complete tasks more efficiently, allowing for faster execution of complex drafting and design tasks. This finding aligns with the research by Boyer et al. [5], which suggests that computer-aided design (CAD) tools enhance students' ability to work faster and more accurately compared to manual drafting methods. Students without access to such tools may struggle to complete tasks simultaneously, leading to slower work completion and potentially a lower overall performance in tasks requiring speed.

Regarding neatness, students with full access to gadgets outperformed their peers with limited or no access, with a mean score of 3.21 (rated as "Satisfactory"), compared to 3.07 for limited access students and 2.89 for those without access. The improved neatness score among students with access to gadgets suggests that these students were better able to produce organized, precise, and well-presented drafts. CAD tools and other drafting software allow for greater precision and easier manipulation of designs, resulting in cleaner and more polished final outputs. This is consistent with the findings of Salvia and Gennaro [23], who highlighted that digital tools improve speed and enhance the quality and neatness of technical drawings. In contrast, there were no significant differences in Legibility or Accuracy between the groups, with all groups scoring similarly within the "Satisfactory" range. This suggests that while access to gadgets has a noticeable effect on the efficiency and presentation of drafts (as reflected in Speed and Neatness), it may not have as direct an impact on the clarity (legibility) or precision (accuracy) of the technical drawings. The consistency in these scores implies that foundational knowledge, manual drafting skills, and spatial reasoning abilities may play a more substantial role in legibility and accuracy than access to technology alone.

The data suggests that access to drafting-related gadgets, such as CAD software or digital drawing tablets, is pivotal in improving student performance in technical drawing tasks. Students with no access to such tools are at a disadvantage in terms of both Speed and Neatness, which could impact their ability to keep up with the pace of work expected in technical fields. The findings are supported by the literature, which emphasizes the advantages of CAD and other digital tools in enhancing the efficiency and quality of technical drawings [1]. In contrast, students without access to these technologies may experience limitations in their ability to produce work efficiently, underscoring the need for equitable access to technology in education.

This highlights the need for educational institutions to consider providing adequate access to technology for all students, especially those in fields that rely heavily on technical drawing and design. As Davis and Durose [9] discuss, unequal access to technology can exacerbate disparities in learning outcomes, as students without access to gadgets may struggle to reach the same performance levels as their peers with full access. Providing students with the necessary tools and training in digital drafting could help bridge this gap, ensuring all students have an equal opportunity to succeed in technical drawing tasks. The findings suggest that access to drafting-related gadgets significantly positively impacts student performance, particularly regarding Speed and Neatness.

Students without access to these tools are disadvantaged, especially when completing tasks efficiently and producing well-organized work. To ensure all students have the opportunity to succeed, it is crucial to address disparities in access to technology, providing the necessary resources and support to foster proficiency in technical drawing. This study found that a combination of factors, including academic performance, sex, family income, SHS track, and gadget access, significantly influenced Drafting Technology students' skills in orthographic projection. Technical track students and those with full access to gadgets tended to outperform their peers, particularly in areas like Accuracy and Legibility. These results suggest that targeted interventions and curriculum adjustments, such as enhancing access to technology and emphasizing technical skills training, could improve students' overall proficiency in orthographic projection.

### 4.8. Differences in the Orthographic Projection Skills of the Students

To further assess the significance of the differences in orthographic projection skills across various groups (e.g., academic performance, sex, family income, SHS track, and gadget access), statistical tests such as t-test for Independent Samples and One-way ANOVA were performed. These tests determined whether the observed differences were statistically significant or could have occurred by chance.

#### 4.8.1. Gender Differences and Orthographic Projection Skills

The table compares orthographic projection (OP) skills—specifically Speed, Legibility, Accuracy, and Neatness—between male and female students. A t-test was conducted to determine whether there are statistically significant differences between the two groups based on sex (Table 7).

**Table 7:** Orthographic Projection (OP) Skills between Male and Female Students

| OP Skills | Sex | | | | |
|---|---|---|---|---|---|
| | **Male** | **Female** | **t-value** | **df** | **Sig** |
| Speed | 3.04 | 3.03 | 0.033 | 88 | 0.974 |
| Legibility | 2.81 | 3.32 | -1.542 | 88 | 0.127 |
| Accuracy | 2.83 | 2.78 | 0.162 | 88 | 0.974 |
| Neatness | 3.02 | 3.14 | -0.401 | 88 | 0.128 |

The results show orthographic projection (OP) skills—speed, legibility, accuracy, and neatness—reveal no statistically significant differences between male and female students. The t-test results indicate that gender does not play a defining role in determining proficiency in these aspects of technical drawing. Speed, in particular, showed nearly identical mean scores (3.04 for males and 3.03 for females), with an extremely high p-value of 0.974, indicating no meaningful difference in the pace at which students complete orthographic projection tasks. Similarly, accuracy scores were almost identical (2.83 for males and 2.78 for females), further supporting the conclusion that gender does not influence the precision of students' drawings. Legibility and neatness, however, presented minor variations, with females scoring slightly higher in both areas (legibility: 3.32 vs. 2.81; neatness: 3.14 vs. 3.02). While these differences were not statistically significant (p = 0.127 for legibility and p = 0.128 for neatness), they align with findings in the literature suggesting that females may demonstrate greater attention to detail in technical and artistic tasks [12]. Nonetheless, research also emphasizes that when both genders receive equal training and resources, disparities in spatial abilities and technical drawing proficiency diminish [6]. This supports the idea that environmental factors, such as access to quality instruction and practice opportunities, play a greater role in skill development than inherent gender differences.

These findings challenge earlier studies suggesting that males generally outperform females in spatial reasoning tasks, which are closely linked to orthographic projection skills [13]. Instead, they align with more recent perspectives emphasizing the impact of instructional quality, engagement, and resource accessibility in shaping student outcomes. The results indicate that male and female students can develop strong orthographic projection skills in inequitable learning environments. This underscores the importance of instructional strategies that cater to diverse learning needs rather than relying on gender-based assumptions about technical skill development. The implications of these findings are significant for educators and curriculum designers. Since no substantial gender-based differences were found, instructional approaches should focus on individualized learning strategies that enhance all students' proficiency in speed, legibility, accuracy, and neatness. Additionally, the slight trend of higher legibility and neatness scores among female students may warrant further investigation, particularly through qualitative studies exploring student attitudes and approaches to technical drawing. Future research could also examine how instructional interventions, such as integrating CAD software [24] or augmented reality [30], impact skill development across different student demographics.

#### 4.8.2. Senior Highschool Track and Orthographic Projection Skills

Results on the study of orthographic projection (OP) skills—speed, legibility, accuracy, and neatness—compared students from technical drawing allied tracks and non-technical drawing allied tracks to determine whether prior exposure to technical drawing-related subjects influences proficiency. The results indicate significant differences in speed and accuracy, while the two groups' legibility and neatness remain largely similar (Table 8).

**Table 8:** Orthographic Projection Skills Across Academic Tracks

| OP Skills | Track | | | | |
|---|---|---|---|---|---|
| | **Technical drawing allied track** | **Non-technical drawing allied tract** | **t-value** | **df** | **Sig** |
| Speed | 3.42 | 3.07 | .206* | 88 | 0.017 |
| Legibility | 3.11 | 3.02 | -0.003 | 88 | 0.998 |
| Accuracy | 3.77 | 2.84 | .266* | 88 | 0.041 |
| Neatness | 3.08 | 3.02 | 0.301 | 88 | 0.764 |

Students from the technical drawing allied track demonstrated a significantly higher mean score in speed (3.42) compared to their peers from the non-technical drawing allied track (3.07), with a p-value of 0.017. This suggests that prior academic exposure to technical drawing disciplines enhances students' ability to execute orthographic projection tasks more efficiently. This finding aligns with research by Kelly & Graham [16] and Lee et al. [18], who highlight that foundational knowledge in geometry and engineering drawing improves spatial visualization skills, leading to faster completion times in technical drawing tasks. The ability to interpret and generate projections quickly is often linked to familiarity with projection principles, which students in technical tracks are more likely to have developed through structured coursework. Similarly, accuracy scores were significantly higher among students in the technical drawing allied track (3.77) than those in the non-technical drawing allied track (2.84), with a p-value of 0.041. This suggests that students with prior exposure to technical drawing concepts are more precise in representing objects in two dimensions, likely due to a stronger grasp of projection rules and conventions. Harris & Yang [14] emphasize that early exposure to geometric principles directly enhances proficiency in orthographic projection by fostering an intuitive understanding of spatial relationships. The significant difference in accuracy also supports the idea that students without a technical drawing background may struggle with visualizing and translating 3D objects onto 2D planes—a skill heavily reinforced in technical drawing courses.

In contrast, legibility and neatness did not show significant differences between the two groups. Legibility scores were nearly identical (3.11 for technical track students vs. 3.02 for non-technical track students, $p = 0.998$), indicating that prior exposure to technical drawing does not necessarily lead to more readable sketches. Similarly, neatness scores were close (3.08 vs. 3.02, $p = 0.764$), suggesting that students from both tracks exhibit similar levels of drawing cleanliness and organization. These findings align with Belete [3], who noted that neatness and legibility in drafting are often influenced by individual work habits rather than academic background. Furthermore, Riley & Smith (2023) suggest that these aspects can be improved through practice and instructor feedback rather than prior exposure to technical drawing courses.

#### 4.8.3. Implications for Teaching and Learning

The results highlight the importance of prior academic exposure in developing speed and accuracy in orthographic projection. This underscores the value of integrating foundational geometry and technical drawing principles into the curriculum for students who may not have taken specialized drafting courses. Since accuracy is a key component of technical drawing success, educators could introduce remedial instruction or targeted exercises for students from non-technical backgrounds to bridge the gap in precision. Additionally, the lack of significant differences in legibility and neatness suggests that these skills can be developed regardless of prior coursework, emphasizing the role of instructional techniques, student effort, and practice in refining these aspects. Future research could explore how instructional interventions—such as the use of 3D models [27] or CAD software [24] can help students from non-technical backgrounds improve speed and accuracy in orthographic projection. Moreover, examining how metacognitive strategies [31] influence students' technical drawing performance could provide insights into how learning approaches impact skill development across different academic tracks.

Overall, these findings reinforce the idea that students with a background in technical drawing develop stronger spatial visualization skills and technical accuracy. Still, legibility and neatness remain skills that can be improved through proper instruction and practice. Educational institutions should consider incorporating structured skill-building workshops or bridge programs to support students from non-technical drawing tracks in developing proficiency in orthographic projection.

#### 4.8.4. Orthographic Projection Skills and Academic Performance

The analysis results indicate that academic performance in technical drawing-related subjects does not significantly influence students' proficiency in orthographic projection (OP) skills, including speed, legibility, accuracy, and neatness. Given that all p-values exceed 0.05, there is no statistically significant difference in OP skills across students with varying levels of academic achievement. This suggests that having high grades in technical drawing subjects does not automatically translate to superior drafting abilities. For speed, the F-ratio of 0.333 with a p-value of 0.718 suggests that students who perform well academically do not necessarily complete orthographic drawings faster than those with lower grades. This result aligns with the findings of Wright and Jones [29], who argue that technical drawing speed is influenced more by practice and familiarity with drafting techniques rather than classroom performance. Some high-achieving students may focus more on theoretical understanding rather than speed. In contrast, others who frequently engage in hands-on drafting exercises may develop quicker execution skills regardless of their academic standing.

Regarding legibility, the F-ratio of 0.835 and a p-value of 0.437 indicate no significant differences among students based on academic performance. High academic achievers do not necessarily produce clearer or more readable drawings than their lower-performing peers. Ching [7] and Cruz [8] point out that legibility is often a product of personal drawing techniques, motor skills, and experience rather than purely academic knowledge. Some students may have excellent conceptual understanding but struggle with executing neat, well-proportioned lettering and line work, affecting their drawings' clarity (Table 9).

**Table 9:** ANOVA results on Orthographic Projection Skills and Academic Performance

| Performance | | | | | | |
|---|---|---|---|---|---|---|
| **OP Skills** | **Source of Variations** | **Sum of Squares** | **df** | **Mean Square** | **F-ratio** | **Sig** |
| | Between Groups | 1.51 | 2 | 0.755 | 0.333 | 0.718 |
| Speed | Within Groups | 197.39 | 87 | 2.269 | | |
| | Total | 198.9 | 89 | | | |
| | Between Groups | 4.106 | 2 | 2.053 | 0.835 | 0.437 |
| Legibility | Within Groups | 213.849 | 87 | 2.458 | | |
| | Total | 217.956 | 89 | | | |
| | Between Groups | 1.893 | 2 | 0.947 | 0.528 | 0.591 |
| Accuracy | Within Groups | 155.896 | 87 | 1.792 | | |
| | Total | 157.789 | 89 | | | |
| | Between Groups | 0.85 | 2 | 0.425 | 0.23 | 0.795 |
| Neatness | Within Groups | 160.75 | 87 | 1.848 | | |
| | Total | 161.6 | 89 | | | |

For accuracy, the $F$-ratio of 0.528 and a $p$-value of 0.591 suggest that students with higher academic grades do not necessarily create more precise orthographic drawings. This is somewhat surprising, as accuracy is fundamental to technical drawing education. However, the lack of significance may indicate that academic grading in technical drawing courses often emphasizes theoretical knowledge, problem-solving, and conceptual understanding rather than manual precision. Research by Anderson and Moore [1] highlights that some students who grasp orthographic projection principles conceptually may struggle with manual drafting but excel in accuracy when using CAD software, where digital tools compensate for human error. Similarly, neatness is not significantly influenced by academic performance, as shown by the $F$-ratio of 0.23 and a $p$-value of 0.795. This finding reinforces the argument that neatness is more of a personal trait than an academically acquired skill. Graham and Hoskins [12] suggest that some students naturally develop more structured and well-organized drawing habits, while others prioritize functionality over aesthetics. While neatness can enhance the presentation of a drawing, technical drawing assessments often prioritize correctness, accuracy, and adherence to standards over tidiness, as noted by Sweeney and Foster [25].

The results suggest that technical drawing knowledge and OP skills develop independently to some extent. Students who perform well in academic assessments may not necessarily excel in manual drafting, while those with lower grades may still demonstrate strong OP skills through practical experience. One possible explanation for this disconnect is the emphasis on theoretical learning in technical drawing courses. Many programs focus on projection methods, dimensioning rules, and drafting standards, which are essential but do not always translate into strong execution skills, as Becker and Carlson [2] suggest. Experience also plays a role in skill development, with some students improving their OP skills through extracurricular practice, internships, or personal projects rather than classroom instruction alone, as Bernstein [4] explains. The increasing reliance on digital tools such as CAD software further contributes to this trend. Siminialayi and Fomsi [24] argue that students who primarily work with digital drafting tools may struggle with manual accuracy and neatness since digital platforms provide error correction features. A more balanced approach to teaching technical drawing is necessary to address the gap between academic performance and OP proficiency. Ensuring that students spend sufficient time practising manual drafting alongside theoretical instruction can help bridge the gap between conceptual knowledge and execution. Incorporating CAD and manual drafting together is also essential, as students should develop fundamental manual skills to strengthen their accuracy and technical precision. Providing individualized feedback to students who excel in theory but struggle with execution can help them refine their OP skills. Given that OP proficiency does not strongly correlate with grades, assessing drawing skills separately through practical performance-based evaluations may also be beneficial, as Sweeney and Foster [25] suggest.

Overall, the findings indicate that academic success in technical drawing courses does not guarantee proficiency in OP skills. While strong academic performance reflects a solid understanding of technical drawing principles, practical execution depends on additional factors such as experience, motor skills, and familiarity with drafting tools. These results highlight the need for a well-rounded approach to technical drawing education, ensuring students develop theoretical knowledge and practical drafting competence. Future studies should further investigate the role of spatial reasoning, hands-on training, and digital drafting tools in shaping OP proficiency.

#### 4.8.5. Orthographic Projection Skills and Family Income

Results on orthographic projection (OP) skills concerning monthly family income reveal no significant effect of income on OP proficiency in speed, legibility, accuracy, or neatness. The $p$-values for all OP skills—speed (0.718), legibility (0.388), accuracy

(0.74), and neatness (0.494)—exceed the 0.05 threshold, indicating that variations in family income do not significantly influence students' performance in these areas (Table 10).

**Table 10:** ANOVA Results on Orthographic Projection Skills and Monthly Family Income

| Monthly Family Income | | | | | | |
|---|---|---|---|---|---|---|
| **OP Skills** | **Source of Variations** | **Sum of Squares** | **df** | **Mean Square** | **F-ratio** | **Sig** |
| | Between Groups | 1.51 | 2 | 0.755 | 0.333 | 0.718 |
| Speed | Within Groups | 197.39 | 87 | 2.269 | | |
| | Total | 198.9 | 89 | | | |
| | Between Groups | 4.689 | 2 | 2.344 | 0.956 | 0.388 |
| Legibility | Within Groups | 213.267 | 87 | 2.451 | | |
| | Total | 217.956 | 89 | | | |
| | Between Groups | 1.089 | 2 | 0.544 | 0.302 | 0.74 |
| Accuracy | Within Groups | 156.7 | 87 | 1.801 | | |
| | Total | 157.789 | 89 | | | |
| | Between Groups | 2.6 | 2 | 1.3 | 0.711 | 0.494 |
| Neatness | Within Groups | 159 | 87 | 1.828 | | |
| | Total | 161.6 | 89 | | | |

For speed, the *F*-ratio of 0.333 and a *p*-value of 0.718 suggest that regardless of income level, there are no substantial differences in how quickly students can complete orthographic drawings. This result is consistent with studies indicating that drafting speed is largely influenced by the frequency of practice and familiarity with the drawing process rather than socioeconomic background [7]. Students from various income levels may access similar levels of practice or gain similar skills through instructional settings, which might explain the lack of income-related differences in drawing speed. Regarding legibility, the *F*-ratio of 0.956 and a *p*-value of 0.388 further support the absence of a relationship between income and drawing clarity. The legibility of technical drawings is influenced more by individual effort, attention to detail, and drawing habits rather than family financial status. Cruz [8] emphasized that legibility in technical drawing is a skill that develops through repeated practice and exposure to drafting techniques, which students from different income backgrounds can equally achieve if they are provided with adequate resources and instruction.

For accuracy, the *F*-ratio of 0.302 and a *p*-value of 0.74 show no significant effect of family income on the precision of orthographic projections. This outcome aligns with findings by Anderson and Moore [1], who suggested that accuracy in technical drawings depends more on understanding drafting principles and hands-on experience than on external factors like income. While socioeconomic factors might influence access to resources like CAD software or textbooks, the focus in drafting education should be on providing equal access to tools and practice opportunities, regardless of a student's financial background. Similarly, neatness, with an *F*-ratio of 0.711 and a *p*-value of 0.494, also shows no significant variation across different income groups. Neatness in technical drawing is often a personal attribute and habit, not strictly determined by financial means. As noted by Sweeney and Foster [25], the quality of one's drawings in terms of neatness is influenced by the individual's dedication to the craft, their practice habits, and their familiarity with drafting standards rather than their family's financial situation. These suggest that family income does not play a significant role in shaping students' OP skills. While students from wealthier families may have greater access to educational resources and technology, this analysis's lack of significant results indicates that, in the context of technical drawing education. This highlights the importance of ensuring that all students, regardless of their socioeconomic background, have access to quality instruction and resources that will allow them to succeed in mastering technical drawing skills.

#### 4.8.6. Access to Gadget and Orthographic Projection Skills

Regarding orthographic projection (OP) skills concerning access to gadgets, results show a marginal influence on speed but no significant impact on legibility, accuracy, or neatness (Table 11). The *p*-value for speed is 0.064, close to the 0.05 threshold for statistical significance, suggesting a potential trend but not a definitive effect of gadget access on drawing speed. On the other hand, legibility, accuracy, and neatness all show *p*-values greater than 0.05, indicating no significant relationship between access to gadgets and these aspects of OP skills. For speed, the *F*-ratio of 2.833 and the *p*-value of 0.064 suggest that students with varying access to gadgets may exhibit different drawing speeds. However, this result is not statistically significant at the 0.05 level. This marginal result could imply that students with access to certain digital tools or gadgets, such as tablets or computers with CAD software, may perform slightly faster due to the efficiencies offered by these tools. However, given the lack of significance, this finding should be interpreted cautiously. Some studies, such as those by Siminialayi and Fomsi [24], argue that while digital tools can speed up the drafting process by automating certain tasks, the learning curve associated with CAD software or other gadgets could offset this potential speed advantage, especially for students with limited experience or access to training.

**Table 11:** ANOVA Results of Orthographic Projection Skills across Gadget Access

| Access to Gadget | | | | | | |
|---|---|---|---|---|---|---|
| **OP Skills** | **Source of Variations** | **Sum of Squares** | **df** | **Mean Square** | **F-ratio** | **Sig** |
| | Between Groups | 12.163 | 2 | 6.082 | 2.833 | 0.064 |
| Speed | Within Groups | 186.737 | 87 | 2.146 | | |
| | Total | 198.9 | 89 | | | |
| | Between Groups | 0.02 | 2 | 0.01 | 0.004 | 0.996 |
| Legibility | Within Groups | 217.935 | 87 | 2.505 | | |
| | Total | 217.956 | 89 | | | |
| | Between Groups | 0.561 | 2 | 0.28 | 0.155 | 0.857 |
| Accuracy | Within Groups | 157.228 | 87 | 1.807 | | |
| | Total | 157.789 | 89 | | | |
| | Between Groups | 1.544 | 2 | 0.772 | 0.42 | 0.659 |
| Neatness | Within Groups | 160.056 | 87 | 1.84 | | |
| | Total | 161.6 | 89 | | | |

In contrast, legibility shows no significant relationship with gadget access, with an $F$-ratio of 0.004 and a $p$-value of 0.996. This finding indicates that access to gadgets does not appear to affect the clarity or readability of technical drawings. Cruz [8] noted that legibility is primarily influenced by the individual's attention to detail and drawing practices rather than the tools used. Whether they use manual drafting tools or digital gadgets, students must focus on neatness and precision to produce legible drawings, suggesting that the influence of technology on legibility is minimal. Similarly, the accuracy analysis reveals no significant effect of gadget access, with an $F$-ratio of 0.155 and a $p$-value of 0.857. This suggests that whether students use gadgets or not does not directly impact the accuracy of their orthographic projections. Anderson and Moore [1] argue that accuracy in technical drawing relies more on understanding projection principles, attention to detail, and experience with drafting rather than on the tools or gadgets used. Therefore, while CAD tools can aid in reducing human error, the basic principles of accuracy are rooted in the student's knowledge and skill in technical drawing.

For neatness, the $F$-ratio of 0.42 and $p$-value of 0.659 indicate no significant relationship between gadget access and the overall neatness of drawings. This suggests that neatness is more influenced by the student's drawing habits and organizational skills rather than the gadgets available. As Sweeney and Foster [25] suggest, neatness is a habit cultivated over time through consistent practice and careful attention to detail rather than being directly linked to technological tools. Results suggest that while access to gadgets may marginalise drawing speed, it does not significantly influence legibility, accuracy, or neatness. This underscores the importance of focusing on traditional drafting skills and consistent practice alongside technological tools. Although digital tools such as CAD software can support technical drawing education, fundamental drawing skills, accuracy, and neatness are not solely dependent on gadget access. Ensuring all students have access to physical and digital resources and strong instruction and practice opportunities is key to developing proficiency in orthographic projection. Further studies could explore how the quality of training on gadgets or the specific types of gadgets used affect students' overall proficiency in technical drawing.

## 5. Conclusion

The study highlights the significant role of academic background and specialized training in shaping students' performance in technical drawing. Students from Technical Drawing Allied Tracks outperformed their peers in speed, accuracy, and slightly in neatness, emphasizing the value of technical education. Additionally, gender differences were observed in legibility, with female students excelling, but external factors such as family income and access to gadgets had limited influence across all dimensions. The findings suggest that while technical training and academic performance are crucial in enhancing technical drawing skills, socioeconomic factors play a lesser role. These results align with existing research on the benefits of specialized education and subtle gender differences in tasks requiring attention to detail and fine motor skills.

### 5.1. Recommendation

The study recommends integrating specialized technical drawing courses early in secondary education, particularly for students in tracks like the Technical Drawing Allied Track, to build spatial reasoning and visualization skills. Gender differences in legibility should be addressed with tailored teaching strategies that support male and female students, fostering confidence in spatial visualization. Ensuring equitable access to technology, including CAD software and digital tools, is essential, especially in underfunded areas, while emerging technologies like AR and VR could enhance students' 3D-to-2D visualization skills. Lastly, although socioeconomic status did not significantly affect orthographic projection skills, providing equal access to instructional materials and resources is crucial for all students to succeed.

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