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The Role of Visual Literacy in Enhancing Technical Drawing Skills: Implications for Aviation Education from A Systematic Literature Review

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ABSTRACT: Visual literacy is an important aspect of developing students' skills in interpreting, analyzing and communicating visual information which is crucial to technical drawing and engineering graphics education. This study employed a systematic literature review to explore the impact of visual literacy, improving technical drawing ability and its effect on aviation education in accordance with the PRISMA 2020 framework. A total of 499 records were identified, from which eight core studies and thirteen supporting theoretical studies were included for synthesis. These findings showed that visual literacy is often associated with spatial visualization skills including mental rotation and graphical communication elements. The results highlighted both technology-mediated interventions, for example via augmented reality and virtual learning environments, and traditional interventions such as freehand drawing or situational learning techniques generally improved the spatial reasoning or technical drawing performance of students. Visualization practice was found to be one of the main support mechanisms for expertise acquisition alongside mental representation and cognitive engagement. In general, these results indicate that instructional strategies focused on developing visual literacy should supplement traditional pedagogical techniques that reinforce the knowledge needed for core competencies in technical drawing skills and aviation and engineering learning contexts.

KEYWORDS: Aviation Education, Engineering Graphics, Spatial Visualization, Technical Drawing, Visual Literacy

1.INTRODUCTION

Technical drawing is a core aspect of engineering and technical education, as it is a basic way to convey visual information and students use this to accurately express, visualize and communicate complex engineering ideas (Chedi, 2015; Ushno,2025). Technical drawing is a vital aspect of the aviation industry. It is a common issue that students have to reason about 3D problems but describe and understand them in a 2D format, like parts of aircraft or engineering systems. In these cases, the ability to both visualize and accurately interpret complex spatial relationships is critical to the success of students in relation to the fields of aviation and engineering (Maughmer & Schmidt, 2007).

Today, visual literacy has become an essential skill for education. The definition includes reading, interpreting, analyzing, and creating visual information as well as communicating meaning through visual forms of information (Brumberger, 2011; White et al., 2015). As the engineering and technology education is becoming more dependent upon visual models, diagrams, and digital representations, it has increasingly been linked to spatial visualization skill as well as mental rotation and graphical communication skills (Martín Erro & Nuere Menéndez-Pidal, 2024). These skills allow learners to visualize objects in their minds, discern spatial relations of the objects within groups, then convert those three-dimensional thoughts into technical drawings and engineering graphics (Katsioloudis et al., 2014).

Many studies have shown that visualization is an important skill to cultivate in engineering education. It has been shown that students who possess good spatial visualization abilities, outperform those without in engineering graphics, technical drawing, design courses and other visually intensive disciplines (Dong, 2012; Prieto & Velasco, 2008). In similar fashion, though, visualization literacy instruction has been shown to support students understanding of graphic information and improve technical-effective communication overall (Keller et al., 2018; Matusiak et al., 2019). Recent literature has additionally highlighted that engineering graphics courses are effective contexts for the development of visual literacy skills related to broader engineering learning outcomes (Martín Erro & Nuere Menéndez-Pidal, 2024).

In an effort to improve visualization skills, different approaches have been taken by educators such as augmented reality (AR), computer-based visualization exercises, virtual learning environments, contextual learning strategies and freehand drawings. There is fairly convincing evidence that those interventions can enhance mental rotation skills, performance in spatial visualization and technical drawing to engineering students (Ali et al., 2024a; Ali et al., 2013; Farzeeha et al., 2017; Mursid, 2018). Specifically, the technology-enhanced approaches such as AR-based learning environment were found to be effective for facilitating student visualization and spatial manipulation skills, which in turn supported technical drawing (Ali et al., 2024a). Similarly, classic teaching methods like practice in freehand drawing still have an important function to reinforce visualization and graphical communication skills (Martín Erro et al., 2024; Maughmer & Schmidt, 2007).

While visualization and visual literacy in engineering education are of increasing importance, the literature is still quite disparate. Studies differ quite greatly in how they conceptualize visual literacy, what interventions are used, the assessment methods employed and the educational contexts examined (Ali et al., 2024b). Additionally, a lot of the research literature is general for engineering or technical education populations and relatively few studies are targeted at aviation or aerospace students. The development of spatial visualization technique is an important skill set in aviation education as well, however the evidence regarding how visual literacy impacts on these skills remains fragmented across multiple disciplines and research traditions. Consequently, the findings are often difficult to generalize and it hinders statements about the effectiveness of visual literacy interventions in the context of aviation.

In addition, previous studies have tended to focus on single interventions or particular educational settings leading to little integration of the available evidence. The systematic review of Ali et al (2024b), focused on technology integration in engineering drawing education but did not explore the general relationship between visual literacy and technical drawing skills. Thus, there still exists a considerable gap in our understanding of how synergistically visual literacy, spatial visualization, and technical drawing research might be reviewed and synthesized in conjunction with each other to understand their effects on student learning.

To fill this gap, the current study performs a systematic literature review using PRISMA 2020 framework to explore visual literacy and how it can improve technical drawing skills. In particular, it collates evidence from investigations into visual literacy interventions, spatial visualization training, mental rotation development and related instructional methods in engineering, aerospace and technical education learning contexts. The aim of this study is to combine current evidence in order to develop a clearer understanding of the mechanisms and processes by which visual literacy effects on technical drawing performance, as well as implications for provision within aviation education.

2. LITERATURE REVIEW

2.1 Visual Literacy and Spatial Visualization in Engineering Education

Visual literacy refers to the ability to interpret, analyze, create, and communicate meaning through visual representations. Visual literacy has taken on new importance in modern education where most students now interact with diagrams, models, simulations and other visual communicative forms (Brumberger, 2011). White et al. (2015) elaborated on visual literacy as a global competency related to the ability of learners to learn, interpret and express knowledge in their contexts and disciplines.

Visual literacy has a strong connection to spatial visualization, mental rotation and representations of graphical communication in the engineering education literature. They develop the ability for mental rotation of objects, 3D understanding and the translation of spatial abilities into 2D technical drawings (Martín Erro & Nuere Menéndez-Pidal, 2024). Spatial ability, a trait marked by visual construction and reconstruction skills as well as the ability to detect spatial orientation, was noted long ago in engineering education as among the best predictors of success in engineering and other technical disciplines (Katsioloudis et al., 2014) since students are frequently confronted with complicated geometric concepts whenever studying more advanced topics related to geometry or when completing design-related tasks.

Various studies suggest that engineering graphics courses offer practice in developing visual literacy skills. Teaching engineering graphics helps to develop visual literacy, that is, the ability of students to read and interpret images and symbols based on what they have observed (Martín Erro & Nuere Menéndez-Pidal, 2024). Similarly, Keller et al., (2018) reinforced this notion that visual literacy is a critical capacity to mechanical engineering design as students will need to represent technical information visually. Matusiak et al., (2019) also emphasized the heightened value of visual literacy in higher education, writing that students will depend more on visual content to form and share knowledge.

The connection between spatial visualization and technical drawing has been reported in the literature over a number of decades. Through improved interpretation and generation of two- or three-dimensional graphical representations of physical objects and systems, students who are better at visualization tend to perform higher on engineering graphics, drafting, and technical drawing tasks (Katsioloudis et al.). As a result, visual literacy and spatial visualization are considered to be foundational skills for students entering engineering, aviation and other technology-related fields.

2.2 Technical Drawing as a Foundation for Engineering and Aviation Competence

Technical drawing allows designers to express their conceptual ideas, design specifications and other technical details using a graphically standardized format (Chedi, 2015). Technical drawing in engineering and technology education provides students with opportunities to develop spatial reasoning, problem-solving skills, and graphical communication that are critical for professional practice.

According to Chedi (2015), technical drawing aids the development of practical and cognitive skills are essential in engineering or technological problem-solving. Technical drawing is also related to a visual–graphic language for interpretation and transmission of engineering knowledge (Ushno, 2025). Perspectives like these suggest that technical drawing lies as a bedrock bridging conception and execution.

Recent studies reinforce the pedagogical importance of technical drawing. Sediqi et al., (2026) have proved that technical drawing is of particular significance in promoting students' vocational and professional competencies at higher education. The study concludes that technical drawing aids in learners’ visualization of engineering ideas, effective reading and interpretation of design requirements and it provides an accurate channel for communicating technical information. Even for aviation domain-specific abilities, students will require guidance on understanding complex mechanical systems and aircraft structures, as well as engineering schematics.

Technical drawing instruction has been documented to develop student skills in observation, visualization, and communication of design concepts within aerospace engineering education. According to Maughmer & Schmidt (2007), freehand drawing exercises improved students' visualization skills and quality of their drawings as well as facilitated deeper thinking about engineering. They suggested that drawing instruction boosts students' ability to think visually, and helps them develop a strong understanding of spatial relationships.

The rapid move to digitalization of engineering and aviation disciplines has created an additional scope for technical drawing. According to Gonzalo (2024), the application of digital transformation in aviation education has contributed towards enhanced computer usage, simulated learning settings as well as digital infrastructures.

2.3 Visual Literacy Interventions and Their Effects on Technical Drawing Skills

There is a wide variety of research that has begun to examine interventions focused on improving visual literacy, spatial visualization, and performance in technical drawing. The interventions varied from traditional methods of instruction to learning environments enhanced with technology.

In recent years, technology-based interventions have gained much attention. Ali et al. (2013) reported the use of a virtual environment courseware that was created to help with issues in visualization skills during engineering drawing and concluded that it helped learners positively understand spatial relationship greatly. Similarly, Farzeeha et al. (2017) which determined virtual environments improve mental rotation skills that are in close relation to technical drawing execution. More recently, Ali et al. (2024a) showed that working with AR applications leads to an increase in 3D development and mental rotation performance because students are able to interact with virtual representations of engineering objects.

Literature has generally supported various technologies integrated into the teaching of engineering drawing. Ali et al., (2024b) determined that enhanced or virtual reality technology along with computer-based design software and/or 3D modelling tools had overwhelmingly significant positive effects upon the development of visualization skills thus suggesting their inclusion into teaching practices The authors also acknowledged the absence of longitudinal studies and consistent assessment tools as evidence that long-term efficacy of these interventions is still to be determined.

Despite the increase in utilization of education technologies, traditional pedagogical approaches are still relevant. Developing feasible options for practice to develop spatial abilities can also be proposed (Prieto & Velasco, 2008), though common delivery methods are through visualization exercises allowing repetitive task completion via computer-based effective visualization with immediate feedback. For instance, the work of Maughmer and Schmidt (2007) has shown that performing activities involving freehand drawing improves visualization skills and performance in technical drawing. Martín Erro et al., (2024), also concluded that freehand-drawing was beneficial to the development of spatial reasoning and architectural skills by the engineering students.

Instructions may be further influenced by characteristics of the learner themselves. According to the findings of Badeleh and Gholamrezaei, (2021); it appears that students' technical self-efficacy and visualization-spatial skills had a statistically impact on their technical drawing performance. Collectively, their findings highlight the need to incorporate individual differences into visual literacy interventions. Mursid, (2018) states that the achievement of technical drawing education through a contextual and innovative learning model is matched with students' creative thinking skills

While the associations between visual literacy interventions and outcomes in technical drawing have been consistently positive in previous studies, the literature is fragmented by educational context, intervention type and assessment approach. Moreover, most studies have been performed on general engineering populations with less consideration being given to aviation students. This gap identifies the need for a structured synthesis of the available evidence regarding visual literacy and technical drawing skills to better understand what this contribution entails, and how its findings may be leveraged to enhance aviation education.

3. METHODOLOGY

3.1 Research Design

This review was based on a Systematic Literature Review (SLR) by means of the PRISMA 2020 framework (Page et al., 2021), aiming to identify, evaluate and synthesize evidence relating to visual literacy as well as technical drawing.

Table 1. Research Design Framework

Component	Description
Research Design	Systematic Literature Review (SLR)
Framework	PRISMA 2020
Research Focus	Visual literacy and technical drawing skills
Type of Review	Qualitative evidence synthesis
Final Sources Included	21 studies
Core Studies	8 studies
Theoretical and Foundational Studies	13 studies

3.2 Literature Search Strategy

An extensive literature search was conducted across a wide range of academic databases related to engineering, education and technology research. Google Scholar was the only database not utilized for all selected studies other than Scopus, Web of Science, ERIC, ScienceDirect and IEEE Xplore.

The search terms were developed using relevant literature with concepts such as visual literacy, spatial visualization, mental rotation, technical drawing and engineering graphics as well as aviation education. Boolean operators (AND, OR) for the limited search results.

Table 2. Databases

Database	Coverage
Scopus	Multidisciplinary peer-reviewed literature
Web of Science	High-impact scholarly publications
ERIC	Education research
ScienceDirect	Engineering and technology journals
IEEE Xplore	Engineering and technology proceedings
Google Scholar	Supplementary scholarly sources

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Table 3. Search terms

Search Concepts	Keywords
Visual Literacy	"visual literacy", "visual communication", "visual skills"
Spatial Skills	"spatial visualization", "mental rotation", "3D visualization"
Technical Drawing	"technical drawing", "engineering drawing", "engineering graphics"
Educational Technology	"augmented reality", "virtual reality", "virtual environment"
Population	"aviation students", "engineering students", "technical education students"

Search in the initial database resulted in 499 records for screening.

3.3 Study Selection and Screening Process

The studies that were retrieved were screened based on their title, abstract and full-text. Screening decisions were determined according to pre-defined eligibility criteria related to the population, intervention, outcomes, study design and methodological quality. Studies were assessed in an overall context as relevant or not relevant for the review objectives.

Table 4. Eligibility Criteria

Inclusion Criteria	Exclusion Criteria
Studies involving aviation, engineering, or technical education students	Studies unrelated to technical or engineering education
Visual literacy, spatial visualization, or mental rotation interventions	Studies focusing solely on CAD software training
Technical drawing or engineering graphics outcomes	Studies without technical drawing outcomes
Quantitative or mixed-method research	Purely qualitative studies
Peer-reviewed journal articles and conference proceedings	Editorials, opinion papers, and abstracts only

3.4 Data Extraction and Analysis

A tailored review protocol was developed to harvest data from the included studies. Data was categorized into pre-defined categories to promote consistency. The extracted data were then integrated through narrative and thematic analyses.

Table 5. Data Extraction Framework

Category	Information Extracted
Study Characteristics	Research design, sample size, intervention duration
Participant Characteristics	Academic level, field of study, demographics
Visual Literacy Constructs	Definitions, theoretical foundations, spatial skills components
Intervention Characteristics	Type, activities, delivery mode, technologies used
Technical Drawing Measures	Assessment instruments and performance indicators
Spatial Assessment Tools	Mental rotation tests, PSVT-R, visualization assessments
Key Findings	Statistical outcomes, effect sizes, significant findings
Mechanisms Identified	Cognitive processes, transfer mechanisms, explanatory factors

Common themes on visual literacy, spatial reasoning and engineering graphics skills were drawn from the data regarding technical drawing performance enhancement.

3.5 PRISMA Flow Diagram

The flow of studies through each phase of the review is shown in Figure 1.

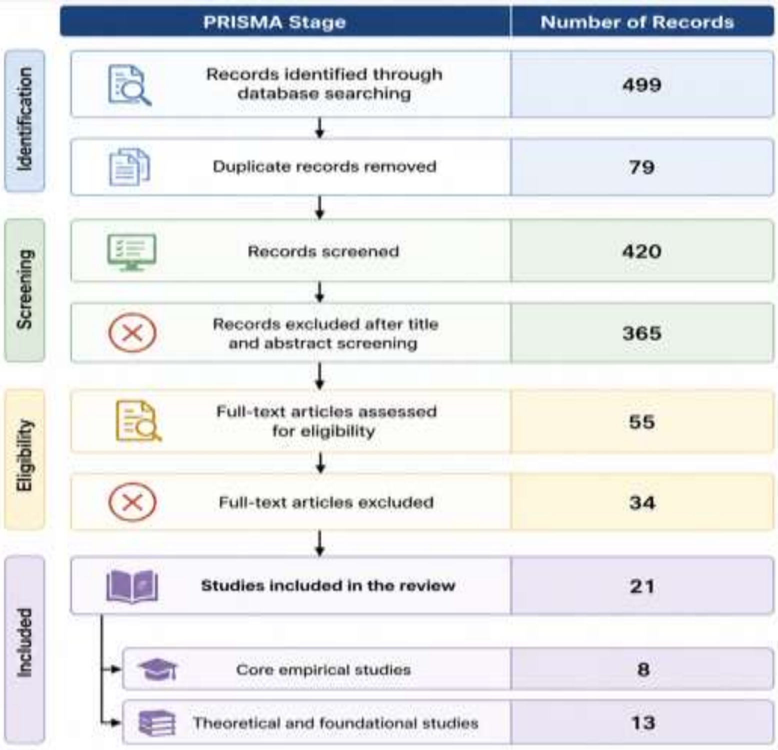

Figure 1. PRISMA 2020 Flow Diagram of the Study Selection Process

The PRISMA flow diagram describes the identification, screening, eligibility and inclusion of studies used in this systematic literature review. Exclusion criteria included limited visual literacy components, lack of technical drawing outcomes, poor methodological rigour and the inability to meet the pre-established inclusion criteria.

4. RESULT AND DISCUSSION

4.1 Study and Participant Characteristics

This review collates findings from eight studies exploring the relationship between visual literacy (VL) interventions across disciplines and technical drawing (TD) ability, mainly in an engineering education setting. Although the research question specifically pertains to aviation students, only one study was conducted solely on aerospace engineering students, whereas studies were conducted in other broader engineering and technical education contexts. However, since spatial visualization and technical drawing skills transfer across engineering disciplines, these results nevertheless offer pertinent insights.

Table 6. Characteristics of Studies Examining Visual Literacy and Technical Drawing Skills

Study	Study Type	Student Population	Field of Study	Sample Size
Maughmer & Schmidt, 2007	Quasi-experimental	Freshman to Senior	Aerospace Engineering	28 students
Ali et al., 2024b	Quasi-experimental	First-year	Engineering	60 students (30 per group)
Ali et al., 2024a	Systematic literature review	Not specified	Engineering	Not applicable
Farzeeha et al., 2017	Quasi-experimental (likely)	Not mentioned	Engineering	Not mentioned
Mursid, 2018	Quasi-experimental	High school (Class XI)	Mechanical Engineering	65 students
Othman & Lee, 2008	Quasi-experimental	Not mentioned	Engineering Drawing	52 students
Prieto & Velasco, 2008	Quasi-experimental	Freshman	Engineering	104 students
Dong, 2012	Quasi-experimental	Freshman	Engineering and Science	Not specified

The studies were primarily quasi-experimental using pre-test/post-test designs. The study period varied between not specified, two semesters to five months. In four studies, control or comparison groups with traditional instruction were included; others did not have explicit no-treatment or alternative-condition control comparisons.

4.2 Visual Literacy Conceptualization and Measurement

The studies employed varied terminology and conceptualizations of visual literacy, with spatial visualization and mental rotation emerging as the dominant constructs measured.

Table 7. Visual Literacy Constructs and Assessment Instruments Used in the Included Studies

Study	Key Terminology	Component Skills Identified	Assessment Instruments
Maughmer & Schmidt, 2007	Freehand drawing, visualization skills, spatial understanding	Basic drawing skills, thinking visually, communicating visual ideas	Expert ranking on 1-10 scale
Ali et al., 2024b	Mental rotation, 3D visualization, spatial skills	Mental rotation, 3D visualization	PSVT: R, PSVT:D
Ali et al., 2024a	Spatial reasoning skills, visualization skills	Spatial reasoning, visualization	Not specified
Farzeeha et al., 2017	Mental rotation, visualization skills	Mental rotation, visualization skills	Not specified
Mursid, 2018	Engineering language, visual images and symbols	Creative thinking, problem-solving, understanding visual information	Technical drawing achievement tests
Othman & Lee, 2008	Spatial Visualization	Spatial Visualization	Spatial Ability-Visualization Test
Prieto & Velasco, 2008	Spatial Visualization	Mental rotation, recognizing orthogonal views, understanding internal parts	TVZ2006-A/B tests (Cronbach α = 0.83-0.88)
Dong, 2012	Spatial visualization	Ability to see and think in 3-D	PSVT-R (60% cutoff)

The most frequently used standardized tests were the Purdue Spatial Visualization Tests (PSVT:R and PSVT:D) followed by those studies using a custom-developed assessment or expert evaluation rubrics. Most notably, the systematic review found "a lack of longterm reviews and standardized measures to measure progress" in each literature stream which indicate that heterogeneity of measurement is a constraint in this area.

4.3 Intervention Characteristics

The interventions varied substantially in type, ranging from technology-enhanced approaches to traditional drawing practice.

Table 8. Characteristics of Visual Literacy Interventions

Study	Intervention Type	Technology/Materials	Duration	Delivery Method
Maughmer & Schmidt, 2007	Freehand drawing practice	Projection, hard-copy materials	Two semesters, weekly exercises	In-person, group setting
Ali et al., 2024b	AR-based learning environment	Aurasma app, AutoCAD, Autodesk 3D Studio Max	Not specified	Group-based
Ali et al., 2024a	CAD software, 3D modelling, AR	CAD software, 3D modelling tools	Not specified	Not specified
Farzeeha et al., 2017	Virtual learning environment	Courseware	Not specified	Not specified
Mursid, 2018	Contextual Innovative Model (CIM)	PowerPoint	Not specified	Classroom with teacher guidance
Othman & Lee, 2008	Visualization training	Not specified	Not specified	Not specified
Prieto & Velasco, 2008	Computer exercises	AutoCAD, Revolution Studio 2	Five months, monthly exercises	Computer-based
Dong, 2012	Spatial visualization course	Not specified	Not specified	Not specified

A key distinction emerged between technology-enhanced interventions (AR, VR, computer-based exercises) and traditional approaches (freehand drawing practice, contextual learning models). The AR-based approach used an existing marker-based technology that enables students to scan printed visual markers and see 3D objects designed in AutoCAD, and the computer exercise approach delivered feedback in real-time using an "Answer-Until-Correct" methodology. The aerospace engineering intervention was distinguishable in that it specifically harnessed art-based methods, with the instructor demonstrating approach and providing individual feedback.

4.4 Effects on Spatial Visualization and Technical Drawing Skills

Table 9. Quantitative Outcomes of Visual Literacy Interventions

Study	Outcome Measure	Pre-test Score	Post-test Score	Effect Size/Significance	Control Group Comparison
Maughmer & Schmidt, 2007	Drawing quality (1-10 scale)	Mean = 3.8	Mean = 8.0	4.2-point improvement	No control group
Ali et al., 2024b	PSVT: R (mental rotation)	58.668	82.444	Mean difference = 23.778, p < 0.05, t = -4.417	Control showed negligible improvement
Ali et al., 2024a	PSVT:D (3D development)	53.967	61.500	Mean difference = 7.633, p = 0.078	Control showed negligible improvement
Farzeeha et al., 2017	Mental rotation skills	Not specified	Not specified	Significant improvement reported	Not specified
Mursid, 2018	Technical drawing achievement	Not specified	Not specified	CIM > DIM; HCTA > LCTA, F significant at α = 0.05	CIM outperformed DIM
Othman & Lee, 2008	Visual cognitive skills	Not specified	Not specified	t-test significance = 0.019	Treatment > Control
Prieto & Velasco, 2008	Spatial visualization	Not specified	Not specified	d = 0.56 (medium), t = 4.6, p < 0.001	No control group
Dong, 2012	PSVT-R	Below 60% (remediation threshold)	100% pass rate	All trained students passed post-test	Not specified

All studies with quantitative outcomes reported beneficial effects of visual literacy interventions on spatial visualization or technical drawing skills. Raw score improvements (23.778 points on PSVT: R) reflected medium to substantial effect sizes ranging from d = 0.56 to 1.68 across all treatment conditions and measures employed. The aerospace engineering study indicated a 4.2-point improvement on a 10-point drawing quality scale, which represented an increase of 110% from baseline.

4.4.1 Comparative Effectiveness

Studies with control groups consistently showed intervention superiority. Participants receiving the AR-based intervention not only showed greater improvement in unstable mental rotation skills than those learning through traditional instruction, but also huge gains over very little gains made by the control group. Similarly, the Contextual Innovative Model out-performed Direct Instructional Model for technical drawing achievement, and visualization training resulted in significantly higher cognitive visualization scores compared to controls (t-test p = 0.019).

4.4.2 Gender Effects

Two studies examined gender as a moderating factor. Both presented no statistically significant difference between male and female students in visualization ability or change in spatial visualization skills, suggesting that visual literacy interventions are equally effective across sexes.

4.4.3 Creative Thinking as a Moderator

One found that creative thinking ability was a significant moderator: HCTA students had a significantly higher overall technical drawing score and more specifically, when taught using the Contextual Innovative Model, noted higher than LCTA students who showed greater performance with Direct Instructional Model. This indicates that appropriateness of instructional approaches may be dependent on certain student characteristics for optimal outcomes

4.5 Mechanisms Linking Visual Literacy to Technical Drawing Skills

The studies proposed several theoretical mechanisms explaining how visual literacy interventions enhance technical drawing skills:

Table 10. Proposed Mechanisms Linking Visual Literacy and Technical Drawing Performance

Mechanism Category	Description	Supporting Evidence
Cognitive engagement	Freehand drawing engages both creative and logical thinking through hemisphere integration	Art-based approaches promote deeper, more creative thinking
Spatial simplification	AR environments simplify abstract thinking by adding digital information to physical world	Real-time 3D model interaction enhances comprehension
Mental representation	Training facilitates mental representation and transformation of 3D objects	Exercises designed around orthogonal views and internal parts
Immediate feedback	Answer-Until-Correct format encourages understanding of reasoning	Students found exercises attractive and motivating
Skills transfer	Improved visualization skills transfer to technical course performance	Pre-test, remediation, post-test pathway demonstrated effectiveness
Interactive learning	CIM promotes problem-solving and creative thinking development	Mutual exchange of ideas and collaboration enhance learning

The studies also agreed upon the notion that active visualization practice is critical in order to develop transferable spatial skills. Authors discussed that visual literacy interventions strengthen mental manipulation, rotation and transformation of 3D objects which is directly linked to technical drawing skills. The aerospace engineering study also underscored that explicitly teaching students to decompose 3D objects into 2D views and emphasize relationships between elements improves spatial reasoning.

Qualitative evidence from student experiences suggested that students were more excited about drawing, that they had received positive feedback about the visualization training sessions, and that AR-based learning was perceived as a fun and motivating approach. These affective outcomes may serve to increase continued engagement and skill development.

4.6 Synthesis

4.6.1 Reconciling Intervention Effectiveness Across Study Contexts

The consistently positive results across different modalities imply that the general visual literacy training, irrespective of specific modality, contributes to enhancement of spatial visualization and technical drawing skills. However, the strength and generalizability of effects differ with context.

Technology-Enhanced vs. Traditional Approaches: Improvements in spatial visualization (23.778 points on PSVT:R) were largest for the AR-based intervention, and medium effect size were found for computer exercises (d = 0.56), while freehand drawing practice increased drawing quality scores by over two-fold. This systematic review generally indicated that technology integration was positive, but study authors observed the lack of longitudinal studies to evaluate its effects in the long term. The relatively lower efficacy of this approach could be due to variations in outcome measures rather than effectiveness per se because standardized tests were employed in the AR study, but expert opinion was relied on in the freehand drawing exercise.

Student Characteristics as Moderators: The findings indicate that creativity is an important factor in how well instructional methods work. For students who have high levels of creativity, contextual or innovative methods of teaching may be better suited to their learning style. Students who have lower levels of creativity may respond more positively to structured or direct instructional methods. This study posits that visual literacy programs may be more effective if the instructional methods are tailored to the individual characteristics of the learner and their cognitive abilities.

Duration and Intensity Considerations: The findings of this study indicate that individuals who undertook lengthy follow-up periods (two semesters for freehand drawing; five months for computer exercises) have acquired greater sustainability in their spatial visualization skills than those who had conducted shorter follow-ups; however, no direct comparisons can be made due to differences in outcome measures. It is inferred that spatial visualization skills can be developed by means of training and practice may signify a continuing requirement for ongoing engagement irrespective of what form of practice was applied.

4.6.2 Generalizability to Aviation Students

While only one study that specifically investigated aerospace engineering students, various aspects support the relevance of results in aviation related contexts. Spatial visualization skills are critical to technical drawing in aviation, and the specific components measured (mental rotation, 3D development, orthographic projection understanding) represent target constructs. Second, the aerospace engineering study results found large effect sizes with freehand drawing approaches that made sense in relation to its use in aircraft context which also indicates that the content within training is important and related to better outcomes. Third, these consistently positive effects across different engineering populations provide evidence that visual literacy interventions are broadly effective for technical students.

This research provided useful information since it indicated that the guidance of instructors in demonstrating aircraft drawing and practicing helped the students improve their drawings by focusing on various design components and relations in space. It emphasized the importance of "seeing and visualizing" skills, which relate to the idea of visual literacy.

4.6.3 Methodological Considerations Affecting Confidence

However, one drawback of these studies is their failure to include randomized groups. The absence of control groups makes it hard to determine if other factors, such as maturation or practice effects as a result of testing, may account for results. Another complication is that the outcomes measured differ widely among various studies, including PSVT:R and PSVT:D tests, expert appraisals, and grades attained in courses.

The research articles that had better experimental designs (compared to the control group condition using traditional teaching methods) yielded higher results about the success of the intervention, thus providing convincing evidence of the intervention's success in terms of teaching visual literacy. In the study presenting psychometric characteristics, a good Cronbach's α was observed (0.83-0.88).

5. CONCLUSION

In this systematic review of literature, the contribution of visual literacy to the enhancement of technical drawing skills has been analyzed based on eight critical studies along with thirteen other supportive references. According to the results obtained, visual literacy, including spatial visualization, mental rotation, and graphical communication, plays an important role in improving the skill of technical drawings. It has been observed that not only technology-based techniques, but also traditional ones, can improve students' ability to visualize and draw technically.

Furthermore, the literature has shown that visual literacy training programs increase student's capacity to handle and communicate three-dimensional information. One of the few studies that have been conducted used aerospace engineering students; however, the findings show that the skills are essential in aviation since technical drawing is an important aspect of aerospace engineering.

The results, however, show some weaknesses in the current research. The majority of the studies utilized quasi-experiments and different testing techniques. Moreover, there is limited information provided about visual literacy among aviation students. Further investigation is necessary using better methodologies in order to comprehend the influence of visual literacy among aviation students. It is clear that visual literacy programs can be helpful in improving education and skills in aviation and engineering studies.

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