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Study of the Difficulties and Challenges Faced by Engineering Students in Engineering Drawing

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Abstract: ***Engineering drawing is a critical skill in the education of future engineers, serving as a foundation for technical communication and design. However, many engineering students encounter significant difficulties and challenges in mastering this subject. This study aims to identify and analyze the common obstacles faced by students in engineering drawing courses, including conceptual understanding, spatial visualization, technical precision, and interpretation of standards and conventions. Data were collected through surveys, interviews, and academic performance analysis from a representative sample of engineering students. Findings reveal that challenges stem from inadequate prior knowledge, limited exposure to practical applications, insufficient teaching methods, and the lack of effective instructional tools. Moreover, the study highlights the role of technology, such as CAD software, as both a learning aid and a potential barrier due to its complexity. Recommendations are provided for educators to enhance learning outcomes through improved pedagogical approaches, integration of interactive tools, and hands-on practice. The results underscore the importance of addressing these challenges to ensure that students develop the necessary proficiency in engineering drawing for their professional careers.***

Index Terms: Engineering Drawing, Technical Drawing Challenges, Engineering Students' Performance, Learning Barriers in Engineering Drawing, Visual Communication Skills, Problem-Solving in Engineering Drawing, Pedagogical Approaches in Engineering Drawing, Student Perceptions of Engineering Drawing.

I. INTRODUCTION

Engineering Drawing, often considered the universal language of engineers, plays a critical role in bridging theoretical concepts and practical applications. It is a cornerstone of engineering education, providing students with the skills necessary to communicate design ideas effectively, interpret technical drawings, and ensure precision in manufacturing and construction processes. Despite its importance, many engineering students face significant difficulties and challenges in mastering this subject. These challenges not only hinder their academic performance but can also impact their professional preparedness.

The complexities of Engineering Drawing arise from its highly visual and technical nature, requiring students to possess a blend of spatial visualization skills, attention to detail, and familiarity with specialized tools and standards. Additionally, the subject demands consistent practice, rigorous application of geometric principles, and an understanding of projection techniques, all of which can be daunting for students with limited prior exposure to such concepts. Moreover, the challenges are often compounded by external factors such as inadequate teaching methodologies, lack of access to modern drafting tools, and insufficient time allocated for practice. Variability in students' educational backgrounds, particularly in terms of mathematical and graphical skills, further exacerbates the problem. As a result, many students struggle to achieve the required level of proficiency, leading to a gap between academic training and industry expectations. This research aims to investigate the specific difficulties and challenges encountered by engineering students in Engineering Drawing. By identifying these issues, the study seeks to propose effective strategies and interventions that can enhance learning outcomes and better equip students for their future roles as engineers. The findings of this research will contribute to the ongoing discourse on improving engineering education and addressing the evolving demands of the field.

II. PURPOSE OF THE STUDY

The purpose of the study is to identify and analyses the key challenges that engineering students encounter when learning and practicing engineering drawing. Engineering drawing is a fundamental skill in the engineering field, essential for the visualization and communication of technical concepts, designs, and solutions. However, many students face difficulties in mastering this subject due to its complexity, the skills required, and the technical nature of the tasks involved. The findings from this study aim to provide insights into the common challenges students face and suggest improvements in teaching methods, resources, and student support to enhance learning outcomes in engineering drawing.

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III. DIFFICULTIES AND CHALLENGES FACED ENGINEERING STUDENTS

Engineering students in Mechanical, Civil, Electrical, and Computer Science and Engineering fields encounter various difficulties and challenges in learning engineering drawing, a crucial skill for visualizing and communicating technical ideas. The challenges vary based on the nature of each discipline, but there are also common struggles across all fields. Below are the key challenges faced by students in these engineering fields:

1) Mechanical Engineering Students

- 3D Visualization and Projection: Mechanical students struggle with visualizing 3D objects and converting them into 2D views (e.g., orthographic projections, isometric views). Understanding how components fit together in real-world applications can be difficult.
- Precision and Detailing: Mechanical drawings require high precision, such as tolerance specifications, material details, and assembly instructions. This level of detail can overwhelm students, especially when dealing with complex components like gears or mechanical systems.
- CAD Software Proficiency: With the shift to Computer-Aided Design (CAD) tools like AutoCAD and SolidWorks, students may find it challenging to transition from manual drawing techniques to digital platforms. Mastering these software tools can take time and requires technical skill.
- Understanding Complex Geometries: Students often struggle to understand and represent complex mechanical parts and assemblies, especially when components involve intricate shapes and multiple views.

2) Civil Engineering Students

- Detailed Drawings for Large-Scale Projects: Civil engineers need to create detailed plans for infrastructure projects, including buildings, bridges, and roads. These drawings involve various details, such as structural elements, materials, and load calculations, which can be overwhelming.
- Compliance with Standards and Codes: Civil engineering drawings must adhere to various national and international standards. Students may struggle to learn and apply these regulations correctly, leading to confusion about required notations and symbols.
- Incorporating Structural Elements: Drawing structural elements like foundations, columns, beams, and reinforcement can be complex, especially when it involves understanding their interactions and ensuring the safety and stability of the designs.
- Integration of Disciplines: Civil engineers must understand how their designs integrate with other engineering fields, such as mechanical systems, electrical wiring, and plumbing. Coordinating these elements in one drawing can be challenging.

3) Electrical Engineering Students

- Circuit Diagram Complexity: Electrical students often struggle with drawing accurate and clear electrical circuit diagrams. Understanding the relationships between components like resistors, capacitors, and transistors in the context of complex systems can be difficult.
- Use of Electrical Symbols: Electrical engineering relies heavily on standardized symbols to represent components. Memorizing and correctly using these symbols in drawings can be a major hurdle for students.
- Power Distribution and Schematic Drawings: Drawing power distribution systems or schematic diagrams involves detailed planning and accuracy. Electrical engineers need to ensure that all power flow paths, connections, and safety measures are accurately depicted, which can be a complex task.
- Software Tools: Similar to mechanical engineering, electrical students must learn how to use specialized software for circuit design (e.g., AutoCAD Electrical, MATLAB/Simulink), which can be time-consuming and technically demanding.

4) Computer Science and Engineering Students

- Abstract Nature of Software Design: Computer science students often face difficulties in representing abstract concepts like algorithms, data structures, and program logic through diagrams such as flowcharts and UML (Unified Modeling Language).
- System Architecture Design: Drawing diagrams to represent system architectures, such as hardware-software integration, cloud-based systems, or network topologies, can be complex due to the technical knowledge required to understand the underlying systems.
- Diagramming of Algorithms: Representing algorithms in visual formats like flowcharts or pseudocode can be difficult for students who are more comfortable with code and logic but struggle to express them visually.

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- Hardware and Circuit Design: For students working in embedded systems, understanding and creating hardware designs, such as circuit board layouts or microcontroller connections, can be a difficult extension of their software-focused education.

A. Common Challenges Across All Engineering Disciplines

- Spatial Visualization: Engineering drawing requires students to visualize and represent 3D objects in 2D. This mental transition can be challenging, especially for students who are not used to thinking in three dimensions.
- Complexity of Detail: Most engineering drawings require a significant amount of detail, from dimensioning to annotations. Students often find it difficult to balance the accuracy and clarity of the drawings without overcrowding them.
- Lack of Hands-On Experience: While students are taught theoretical concepts, many lack opportunities for hands-on practice, which can make it difficult to apply what they learn in class to real-world situations.
- Time Constraints and Workload: Engineering drawing assignments are often time-consuming and can add to the overall academic workload. Students may find it challenging to complete high-quality drawings under tight deadlines.
- Learning and Using CAD Software: Regardless of discipline, students need to become proficient in various CAD tools, which can be overwhelming for those who do not have prior exposure to digital drawing or design tools.
- Inadequate Instructional Support: Many students find that the teaching methods used in engineering drawing classes are insufficient, lacking clear demonstrations or hands-on practice. Additionally, there may be a lack of resources or one-on-one support available to help them improve their skills.

B. Suggestions To Overcome These Challenges

- Interactive Learning Tools: Using 3D visualization tools, virtual reality, or augmented reality platforms can help students better understand and interact with engineering drawings.
- CAD Training and Support: Providing comprehensive CAD training and offering tutorials or workshops can help students become more proficient with digital drawing tools.
- Collaborative Work: Encouraging students to work in teams or peer-review each other's drawings can promote collaborative learning and enhance understanding.
- Regular Practice: Frequent, well-structured practice assignments and projects help students refine their skills and build confidence in their drawing abilities.
- Incorporating Real-World Projects: Integrating real-world examples or industry-related projects into the curriculum can help students connect theory with practice, making engineering drawing more meaningful.

By addressing these challenges and improving teaching strategies, engineering students can enhance their ability to produce accurate, detailed, and functional engineering drawings, essential for their future careers.

IV. RESEARCH QUESTIONS FOR PROBLEM SOLVING

A. What are the common difficulties faced by engineering students in understanding engineering drawing concepts?

Engineering students, regardless of their discipline, face several common difficulties in understanding **engineering drawing concepts**. These challenges stem from the complexity of the subject, the need for precise attention to detail, and the visualization skills required. Some of the most common difficulties include:

1) Spatial Visualization and 3D Interpretation

- One of the biggest challenges is the ability to mentally visualize three-dimensional objects and convert them into two-dimensional representations (and vice versa). Students often struggle to grasp how various views (e.g., front, top, side) correlate with each other and how they fit together to form the complete object.
- For example, visualizing complex shapes, mechanical parts, or architectural structures in different orientations is difficult for many students.

2) Understanding Different Types of Projections

- Orthographic Projections (e.g., front, top, side views) and Isometric Views are crucial techniques in engineering drawing. Students often have difficulty understanding how to correctly create and interpret these projections. Knowing how to draw objects in multiple views while maintaining consistency in measurements and proportions is a common hurdle.
- Similarly, axonometric projections (such as isometric or dimetric views) can confuse students due to their non-standard angles and the use of scaling along multiple axes.

3) Accuracy in Scaling and Dimensioning

- Proper scaling is essential in engineering drawings. Students often have trouble applying the correct scale to their drawings, especially when transitioning from smaller to larger-scale representations. Misunderstanding or incorrectly applying dimensions can lead to inaccurate drawings that do not correspond to real-world measurements.
- Dimensioning requires students to follow specific conventions and use clear, standardized methods for indicating the size, shape, and tolerance of components.

4) Use of Symbols and Notations

- Engineering drawing uses a wide range of symbols, lines, and notations to convey information. Students often find it challenging to memorize and correctly apply these symbols for different materials, components, or geometric shapes.
- There are also specific conventions for line types, dimensioning styles, and notations for surface finishes that must be understood and followed meticulously.

5) Understanding of Sectional Views and Details

- Creating and interpreting sectional views (views that represent "cut" sections of an object) can be a difficult concept for students to master. Understanding when to use a section view, how to cut through the object, and how to represent internal features can cause confusion.
- The challenge is compounded when dealing with detailed drawings that require multiple section views to fully describe an object.

6) Complex Geometries and Curves

- Drawing and interpreting complex curves, fillets, radii, and angles can be particularly difficult for students, especially when these shapes need to be represented accurately in multiple views. Understanding the principles of geometric constructions and how they relate to practical designs is often a struggle.
- For instance, when designing mechanical parts like gears or pistons, students may have difficulty translating 3D curves into 2D representations.

7) Transitioning from Manual to Digital Drawing

- Many students face a transition from traditional hand-drawing techniques to computer-aided design (CAD) software. While CAD tools (e.g., AutoCAD, SolidWorks) are widely used in engineering, the learning curve for these digital tools can be steep for those who are more accustomed to manual methods.
- The software interface, precision in digital drawing, and use of advanced features (like 3D modeling) can initially be overwhelming.

8) Interdisciplinary Integration

- Engineering drawings often require students to integrate concepts from different engineering disciplines. For example, civil engineering students need to consider structural, mechanical, and electrical aspects of a design in a single drawing, while mechanical engineering students may need to incorporate electrical components into their designs.
- Balancing the needs and standards of various disciplines in one cohesive drawing can be a challenge, especially when working on multi-disciplinary projects.

9) Lack of Practical Exposure and Hands-On Practice

- Engineering drawing is a skill that requires frequent practice and real-world application. However, many students do not get enough opportunities for hands-on practice, making it difficult for them to apply theoretical knowledge to actual drawing tasks.
- Without enough practical exposure, students may struggle to understand how to apply concepts in the context of actual engineering projects, which can make drawing feel abstract and disconnected from real-world applications.

10) Time Management and Workload

- Engineering drawing assignments often involve considerable time and effort due to the level of detail required. Many students struggle with managing their time effectively, particularly when they have multiple assignments and projects from other engineering subjects.

- This can lead to rushed or incomplete drawings, where accuracy and precision may be compromised due to time constraints.

11) Inconsistent Teaching Methods and Lack of Support

- Some students find that the teaching methods used in engineering drawing classes are inconsistent or not adequately supportive. Theoretical lectures may not be accompanied by enough hands-on practice, and individual feedback may be limited.
- Without sufficient guidance, students may not receive the reinforcement needed to fully understand the concepts, leading to confusion and frustration.

B. How do students perceive the teaching methods used in engineering drawing course?

The way students perceive the **teaching methods** used in an **engineering drawing course** can significantly impact their learning experience and mastery of the subject. Students' perceptions often vary based on several factors, including the delivery style of the instructor, the resources provided, and the extent to which practical applications are emphasized. Here are some common perceptions and feedback from students regarding teaching methods in engineering drawing courses:

1) Preference for Hands-On and Practical Learning

- Positive Perception: Many students feel that engineering drawing is a skill that requires a hands-on approach. When instructors incorporate practical exercises, such as drawing assignments, model making, or using CAD software in real-time, students generally respond more positively. Practical sessions allow students to apply theoretical concepts, making learning more engaging and relevant.
- Negative Perception: Students often feel frustrated when the course lacks enough practical exposure or is too focused on theoretical explanations. Without the opportunity to practice, students may struggle to understand how to apply abstract concepts to real-world situations.

2) Value of Visual and Interactive Teaching Tools

- Positive Perception: Students appreciate when instructors use visual aids such as diagrams, animations, 3D models, or digital tools (like CAD) to explain complex concepts. Interactive tools that allow students to manipulate designs, rotate objects, or view drawings from different angles are highly valued as they aid in better spatial visualization.
- Negative Perception: Some students express frustration when instructors rely primarily on traditional chalk-and-board methods, which may not be as effective for explaining complex visual concepts in engineering drawing. Without engaging visual tools, students can find it hard to follow the lessons and may feel disconnected from the material.

3) Instructor's Approachability and Support

- Positive Perception: When instructors are approachable and provide clear, constructive feedback on students' drawings, students tend to have a positive perception of the course. Students value open communication, where they can ask questions, clarify doubts, and receive guidance on how to improve their work.
- Negative Perception: Students often feel disengaged when instructors are unapproachable, offer little individual support, or fail to provide personalized feedback. Inadequate support during office hours or a lack of clear explanations can lead to confusion and a negative learning experience.

4) Pacing and Depth of the Curriculum

- Positive Perception: A balanced curriculum that introduces fundamental concepts and gradually progresses to more complex topics is well-received. Students appreciate when the course is paced well, allowing them to master the basics before moving on to more advanced techniques in engineering drawing.
- Negative Perception: On the other hand, students may feel overwhelmed when the course covers too much content too quickly or dives too deep into complex topics without solid foundational knowledge. When the instructor moves too fast, students may struggle to keep up, leading to frustration.

5) Use of CAD Software and Technology

- Positive Perception: In today's digital age, students generally perceive courses that incorporate CAD software (like AutoCAD or SolidWorks) as more relevant and beneficial. Many students appreciate the opportunity to learn and practice with these tools, as they are industry standards in engineering design. These tools help them understand how drawings transition from paper to digital, which is crucial for modern engineering practices.

- Negative Perception: Some students, especially those with limited prior exposure to computers or digital tools, may feel intimidated by CAD software. If the instructor does not provide sufficient training or support, students may become overwhelmed by the software's complexity and the steep learning curve involved.

6) Feedback Mechanisms and Assessments

- Positive Perception: Students tend to appreciate timely and constructive feedback on their work, which helps them understand their mistakes and improve. Assessment methods that emphasize practical skills—such as reviewing students' drawings and giving clear feedback—are typically seen as helpful.
- Negative Perception: Students often criticize assessments that focus heavily on theoretical knowledge (e.g., tests on terminology or symbols) rather than practical application. They may feel that the course doesn't truly assess their ability to draw or apply engineering concepts in real-world scenarios, which is the primary goal of the subject.

7) Theoretical vs. Practical Balance

- Positive Perception: Students tend to appreciate when the course integrates both theoretical knowledge (e.g., learning about projection systems, symbol usage) and practical exercises (e.g., actual drawing, CAD tasks). A course that ties theory directly to practice helps students understand the real-world importance of engineering drawings.
- Negative Perception: Students may perceive the course as dry or irrelevant if it focuses too heavily on theoretical concepts without offering enough hands-on practice. While theoretical knowledge is essential, without application, students often feel disconnected from the material.

8) Group Work and Collaboration

- Positive Perception: Collaborative work and peer review often receive positive feedback, as students can learn from each other's perspectives and refine their understanding. Working on group projects also simulates real-world collaborative design environments, helping students build teamwork skills.
- Negative Perception: Some students dislike group work, especially if they feel that their teammates are not contributing equally, or if collaboration leads to less individual learning. Additionally, students who prefer individual learning may find group settings distracting or inefficient.

9) Clarity of Course Expectations and Resources

- Positive Perception: Clear communication of course expectations, including what is expected in assignments and assessments, tends to foster a positive perception of the course. When students know exactly what they need to do to succeed and have access to sufficient learning resources (e.g., textbooks, online resources, software tutorials), they feel more confident in their ability to learn and succeed.
- Negative Perception: When course expectations are unclear or when students do not have access to necessary resources (e.g., CAD software, proper drafting tools, lab time), they may become frustrated and feel unprepared. A lack of instructional materials or guidance can hinder students' ability to fully grasp the concepts of engineering drawing.

C. What specific challenges do students face in mastering drawing techniques (e.g., projections, orthographic views, isometric views)?

Students face several specific challenges when mastering drawing techniques such as projections, orthographic views, and isometric views in engineering drawing. These techniques are foundational for representing three-dimensional objects on a two-dimensional surface, and mastering them requires a combination of spatial reasoning, technical skills, and practice. Here are the most common challenges:

1) Spatial Visualization and Understanding 3D to 2D Conversion

- Challenge: The biggest hurdle for many students is the ability to mentally visualize and convert three-dimensional objects into two-dimensional views. This requires strong spatial visualization skills, which many students struggle with.
- Explanation: For example, understanding how an object will appear in various orthographic views (front, top, side) or how it translates into an isometric view can be challenging. Students must comprehend how to extract different views of the same object and represent them accurately.

2) *Mastering Orthographic Projections*

- Challenge: Orthographic projection is a fundamental technique used to represent three-dimensional objects in two dimensions. It involves drawing multiple views (typically front, top, and side views) of an object.
- Explanation: Students often struggle with the correct alignment of these views and the relationship between the different projections. For example, understanding how the top view aligns with the front or side view can be difficult, and students may misplace or distort the proportions of the object when transferring it between views.
- Problem: Misunderstanding the relationship between views leads to disconnected projections and an inaccurate representation of the object.

3) *Understanding Axonometric and Isometric Views*

- Challenge: Isometric views are a type of axonometric projection where the object is tilted along its axes to provide a 3D representation in 2D space. Understanding how to draw objects in an isometric view can be challenging because of the non-parallel axes and the need for consistent scaling.
- Explanation: In an isometric view, all three axes (X, Y, Z) are equally foreshortened, which means that the angles between them are fixed at 120°. Students may find it difficult to apply this foreshortening, maintain proportions, and represent complex objects accurately in isometric projection.
- Problem: Students can struggle with maintaining consistency in the angles and proportions, which often results in distorted drawings or confusion about the object's true shape.

4) *Projection Planes and Third-Angle vs. First-Angle Projection*

- Challenge: Projection planes (theoretical flat planes used to project views of an object) and the distinction between first-angle and third-angle projection methods can confuse students.
- Explanation: First-angle projection involves placing the object between the observer and the projection plane, while third-angle projection places the object on the same side as the projection plane. This difference affects how views are arranged on the drawing sheet.
- Problem: Misunderstanding or switching between these two types of projections leads to confusion, such as drawing misaligned or incorrectly placed views. Many students struggle to remember which projection method they should use for a given task and may mistakenly mix up the view arrangement.

5) *Dimensioning and Detailing of Views*

- Challenge: Properly dimensioning and detailing projections is another significant challenge. Students need to understand how to place dimensions (e.g., length, width, height) and annotations on different views to fully describe an object.
- Explanation: Dimensioning involves understanding which parts of the drawing need to be measured and how to arrange the dimensions clearly, without cluttering the drawing. Students often struggle with dimension placement, tolerances, and ensuring that dimensions are correct for each view.
- Problem: Improper dimensioning can result in unclear or inaccurate drawings, making it difficult to manufacture or interpret the design.

6) *Handling Complex Objects and Hidden Lines*

- Challenge: Representing complex objects with multiple internal features (e.g., holes, grooves, cuts) or hidden details is a significant challenge in orthographic and isometric projections.
- Explanation: In orthographic views, hidden lines are used to represent parts of the object that are not visible from a given view. Students often have difficulty properly representing these hidden lines or understanding when they should be used.
- Problem: Failure to include hidden lines correctly or confusion about which parts should be shown as hidden can make a drawing incomplete or difficult to interpret.

7) *Overcoming the Transition from Manual to Computer-Aided Design (CAD)*

- Challenge: As many courses shift to CAD software (e.g., AutoCAD, SolidWorks) for drawing, students may face difficulties in adapting their knowledge of manual drawing techniques to the digital environment.

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- Explanation: CAD software automates many aspects of drawing, such as scaling, dimensioning, and alignment. However, students still need to understand the fundamental principles behind the projections (orthographic, isometric, etc.) to apply these tools correctly.
- Problem: Students who are not proficient with CAD software may struggle to use the software's features efficiently, leading to frustration and a lack of accuracy in their digital drawings.

8) Handling Complex Geometries and Asymmetrical Objects

- Challenge: Representing objects with complex geometries, such as curved surfaces, irregular shapes, or asymmetrical designs, poses difficulties for students.
- Explanation: Unlike simple geometric shapes, complex objects require students to break down the shapes into basic elements that can be represented in projections. In isometric views, complex shapes must be simplified and represented with clear lines, which can be difficult to achieve accurately.
- Problem: Misunderstanding how to represent these complex features in a clear and organized way can lead to confusion and incorrect drawings.

9) Maintaining Consistent Scale and Proportions

- Challenge: Maintaining scale and proportions in engineering drawings is crucial for accuracy. Students often struggle with applying consistent scales between different views, especially when working with different types of projections or when switching between manual and digital methods.
- Explanation: Each projection method has its own rules for scaling and proportions. In isometric views, for example, students must apply a specific foreshortening factor to ensure the object looks proportionally accurate.
- Problem: Incorrect scaling leads to distorted or unrealistic drawings, making it difficult to communicate the design properly.

10) Time Management and Attention to Detail

- Challenge: Engineering drawing requires attention to detail and precision. Students often face challenges in allocating sufficient time to create high-quality drawings, especially when they need to balance this with other coursework.
- Explanation: Since engineering drawings demand accuracy and thoroughness, students may rush through projects, overlooking important details or making careless mistakes.
- Problem: Lack of time or poor time management can result in incomplete or inaccurate drawings, diminishing the quality of their work.

D. How does the lack of practical experience or resources (such as software tools or drafting equipment) affect students' performance in engineering drawing?

The lack of practical experience or resources, such as software tools or drafting equipment, can significantly affect students' performance in engineering drawing. Engineering drawing requires hands-on practice and the right tools to effectively apply theoretical knowledge. Without these resources, students face a range of challenges that can hinder their understanding and ability to produce accurate, detailed, and professional-level drawings.

1) Limited Skill Development

- Effect: Without adequate practical experience, students struggle to develop the manual dexterity and technical skills needed to create precise engineering drawings. Drawing skills—whether on paper or using CAD tools—are built through consistent practice. If students lack the opportunity to practice drawing by hand or using digital tools, they are unable to gain the necessary proficiency.
- Impact: Students may produce rough or imprecise drawings, leading to poor outcomes in both academic assessments and real-world applications. Their ability to conceptualize and communicate designs through drawings will be limited.

2) Difficulty Understanding and Applying Concepts

- Effect: Engineering drawing involves translating three-dimensional ideas into two-dimensional representations, which requires a high level of spatial reasoning. Theoretical learning alone is often insufficient to fully grasp concepts like projections, orthographic views, and isometric views. Without practical tools and exercises, students have difficulty internalizing these concepts.

- Impact: Students may struggle to translate what they have learned theoretically into actual drawings, leading to confusion about the relationship between different views, projections, and how they should be represented on paper.

3) Inability to Use Advanced Software Tools (CAD)

- Effect: In modern engineering, CAD software (like AutoCAD, SolidWorks, or CATIA) is integral to the drawing process. Students who lack access to CAD software or don't receive adequate training in its use are at a significant disadvantage. These tools allow for precision, speed, and easy manipulation of designs, which are essential for effective engineering drawings.
- Impact: Students who are unable to use CAD software may fall behind in developing critical skills that are expected in the workforce. They may also find it difficult to compete with peers who have practical experience with these tools. Additionally, students may struggle with transitioning to CAD later, which can result in increased difficulty when they encounter professional settings or advanced coursework.

4) Limited Exposure to Real-World Applications

- Effect: Practical experience often includes exposure to real-world applications of engineering drawing, such as working on industry-specific projects, using industry-standard tools, or collaborating with professionals. Without access to these experiences, students may not fully understand the significance of their coursework in a practical context.
- Impact: The lack of real-world exposure limits students' ability to relate classroom learning to actual engineering projects. They may struggle with understanding how engineering drawings fit into the broader context of design, manufacturing, and construction.

5) Increased Dependence on Instructors

- Effect: When students do not have access to appropriate resources or sufficient opportunities for hands-on practice, they become more reliant on instructors for explanations and feedback. While instructor guidance is essential, excessive dependence can inhibit students' ability to develop independent problem-solving skills.
- Impact: Students may not be able to troubleshoot or correct mistakes on their own, leading to a lack of self-confidence and limited problem-solving ability in real-world scenarios. This dependence can also slow down the learning process and hinder the development of practical skills.

6) Challenges in Precision and Accuracy

- Effect: Drafting equipment such as compasses, protractors, rulers, and T-squares are essential for ensuring the precision and accuracy of hand-drawn engineering diagrams. Without these tools, students are more likely to make errors in alignment, scale, or measurements, resulting in inaccurate drawings.
- Impact: Inaccurate drawings can lead to misinterpretations of designs, which is especially problematic in engineering, where small errors can have significant consequences. Students who lack the proper tools may also fail to develop the attention to detail necessary for professional-level work.

7) Increased Frustration and Decreased Motivation

- Effect: The frustration that comes from not having access to proper tools or enough practice can lead to a lack of motivation. When students feel they are unable to meet the expectations due to lack of resources, they may become disengaged and less interested in learning.
- Impact: A decline in motivation can result in lower academic performance and a lack of progress in mastering engineering drawing concepts. Students may also experience increased anxiety, especially when their drawings do not meet expected standards due to lack of resources.

8) Inefficient Learning Process

- Effect: Without access to the right resources, students may find themselves spending more time and effort trying to complete assignments using less effective or outdated methods. They might have to resort to manually drawing designs without the aid of modern CAD tools, which can be time-consuming and lead to less accurate results.
- Impact: This inefficiency can cause delays in completing assignments, as students may need extra time to finish their drawings, especially if they struggle with basic skills. Additionally, students may become frustrated with the time commitment, leading to a lack of enthusiasm for the subject.

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9) Difficulty Transitioning to Professional Environments

- Effect: Many industries require engineers to use advanced drafting tools and software regularly. If students are not exposed to these tools during their academic years, they may struggle when they transition to internships or full-time roles in professional environments.
- Impact: The gap between academic learning and industry expectations can be large, leading to difficulties when students start working in real-world projects. Students who are not familiar with industry-standard tools may need additional training or may find it harder to contribute effectively to team projects.

10) Limited Collaborative Learning Opportunities

- Effect: Collaborative learning in engineering drawing often involves working in groups or interacting with peers who have varying levels of skill. Without the right resources, collaborative efforts may be less effective, as students may struggle to share their drawings or exchange feedback on a common platform.
- Impact: The lack of resources like CAD tools can limit group work, reducing students' opportunities to collaborate effectively. This can result in less interaction with peers, reduced peer learning, and less exposure to different techniques and approaches to solving design problems.

E. What suggestions do students have for improving the teaching and learning of engineering drawing?

Students often have valuable insights into how the teaching and learning of engineering drawing can be improved to enhance their understanding and performance in the subject. Based on common feedback, here are several suggestions that students typically provide for improving the teaching and learning of engineering drawing:

1) Incorporate More Hands-On Practice and Real-World Applications

- Suggestion: Students often emphasize the importance of practical, hands-on practice. They suggest more opportunities for students to practice drawing by hand as well as using CAD software. This could involve assigning more practical projects, group work, or real-world design tasks that require students to apply engineering drawing techniques.
- Rationale: Engineering drawing is a skill that improves with practice, and real-world applications help students connect theoretical concepts to industry practices.

2) Integrate Advanced Software and Tools Early in the Curriculum

- Suggestion: Many students request that CAD tools (like AutoCAD, SolidWorks, or Fusion 360) be introduced earlier in the course. Instead of waiting until later semesters, students suggest integrating software training into the early stages of the course, alongside traditional drawing methods.
- Rationale: As most modern engineering relies heavily on CAD software, early exposure allows students to become proficient in these tools, preparing them for real-world engineering work and making the transition from manual drawing to digital design smoother.

3) Provide More Visual and Interactive Learning Materials

- Suggestion: Students often recommend the use of visual aids like animated demonstrations, 3D models, and interactive tools to help explain complex concepts, such as projections, isometric views, and orthographic drawings. They believe that visualizing how objects change between views can significantly improve understanding.
- Rationale: Engineering drawing is a highly visual subject, and students find that using interactive tools or watching dynamic, step-by-step visual demonstrations can make complex ideas easier to grasp.

4) Offer More Practical Exercises with Constructive Feedback

- Suggestion: Students suggest that instructors provide more opportunities for practice exercises and constructive feedback on their drawings. They feel that feedback should not only be about what is wrong but also provide guidance on how to improve specific aspects of their drawings.
- Rationale: Frequent practice, combined with detailed, timely feedback, helps students identify and correct mistakes while improving their drawing skills. Personalized feedback helps build confidence and proficiency.

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5) *Incorporate Collaborative Learning and Peer Reviews*

- Suggestion: Many students advocate for more group work or peer review activities. By working in teams or reviewing each other's drawings, students can learn different approaches and techniques, fostering collaboration and improving the quality of their work.
- Rationale: Peer learning helps students identify alternative methods of problem-solving and exposes them to a variety of drawing techniques. Additionally, working in groups simulates real-world collaboration in the engineering field.

6) *Clarify the Connection Between Engineering Drawing and Other Disciplines*

- Suggestion: Students often suggest that instructors emphasize how engineering drawing connects to other fields in engineering, such as mechanical design, civil construction, or electrical schematics. By showing the relevance of drawing in various engineering disciplines, students can better understand its importance.
- Rationale: By understanding how drawing is applied in various branches of engineering, students can appreciate the subject's real-world importance and gain a broader perspective on its utility.

7) *Improve the Pacing of the Course and Break Down Complex Concepts*

- Suggestion: Some students find the pace of the course overwhelming, especially when complex topics like projection techniques or isometric drawing are introduced. They suggest that the course be broken into smaller, more manageable sections, with each concept building upon the previous one.
- Rationale: Slowing down the delivery of challenging topics and reinforcing foundational skills before moving on to advanced topics can improve retention and confidence in mastering the material.

8) *Incorporate More Digital Resources, Tutorials, and Online Learning Platforms*

- Suggestion: Many students suggest integrating online tutorials, video lectures, and digital resources that allow them to review material at their own pace outside of class. Providing access to platforms such as YouTube tutorials, online courses, and CAD software practice could greatly enhance their learning experience.
- Rationale: Online resources allow students to reinforce what they've learned in class, review complex concepts, and practice drawing techniques outside of scheduled lessons.

9) *Offer Specialized Workshops or Extra Classes*

- Suggestion: Students often recommend organizing workshops or extra classes that focus specifically on areas where students tend to struggle, such as advanced drawing techniques, CAD tools, or dimensioning practices.
- Rationale: Special focus on specific areas allows students to get more in-depth instruction and practice in areas they find particularly challenging, helping them improve in a targeted way.

10) *Make Use of Real-World Case Studies and Industry Projects*

- Suggestion: Students recommend integrating real-world case studies or industry-sponsored projects into the curriculum. They believe that exposure to actual design problems and constraints would allow them to understand the practical applications of engineering drawing.
- Rationale: Real-world case studies make learning more relevant and motivate students to apply their skills to real engineering challenges. It also provides them with a more holistic understanding of the role of drawing in the engineering design process.

11) *Use a Blended Learning Approach*

- Suggestion: Students often suggest a blended learning approach, which combines traditional face-to-face instruction with online learning. This could involve using a flipped classroom model, where students learn the theory through online resources and engage in practical exercises and discussions during in-person classes.
- Rationale: A blended learning model allows students to control the pace of their learning, review material at their convenience, and focus class time on hands-on practice and clarification of difficult concepts.

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12) Increase Instructor Accessibility and Support

- Suggestion: Students suggest that instructors be more accessible for one-on-one sessions or office hours to provide additional support and guidance on individual projects or assignments.
- Rationale: Personalized support helps students tackle specific challenges they face with engineering drawing, and having regular access to instructors can increase student confidence and comprehension of the subject.

13) Make the Learning Environment More Interactive and Engaging

- Suggestion: Students request a more interactive learning environment, where they can engage with the material through activities like design competitions, drawing challenges, or real-time class discussions.
- Rationale: Engaging students through interactive activities creates a more dynamic learning atmosphere and encourages active participation, which can make the learning process more enjoyable and effective.

14) Provide More Examples and Practice Materials

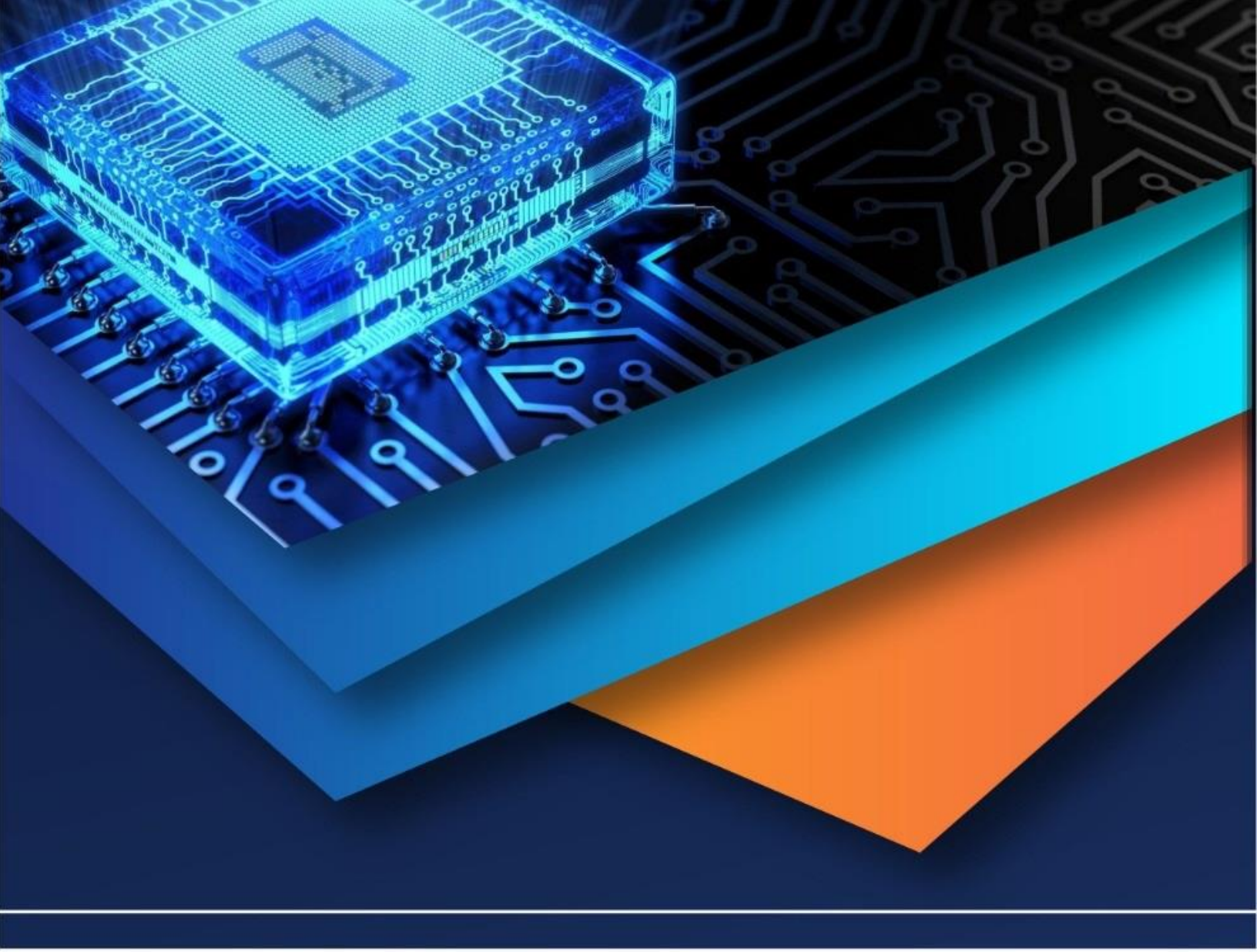
- Suggestion: Students suggest that instructors provide more sample drawings, practice exercises, and step-by-step guides for complex tasks. This would allow them to better understand the correct processes for drawing and to practice replicating professional-grade drawings.
- Rationale: Having access to additional examples and exercises helps students understand the expectations and standards of engineering drawings and provides them with ample practice to hone their skills.

V. CONCLUSION

The study of the difficulties and challenges faced by engineering students in engineering drawing has highlighted several critical areas that hinder students' performance and understanding. These challenges range from a lack of practical exposure and insufficient foundational knowledge to the complexities of mastering technical drawing software. Additionally, inadequate instructional methods and limited access to resources contribute to the difficulties experienced by students in this discipline. To address these challenges, it is essential to implement a more interactive and hands-on approach to teaching engineering drawing. Incorporating modern technologies such as CAD tools, as well as providing more real-world applications, could help bridge the gap between theory and practice. Furthermore, developing personalized and adaptive learning resources, alongside better-trained instructors who can effectively address the diverse learning needs of students, would improve engagement and competency. Ultimately, overcoming these challenges requires a collaborative effort between educational institutions, instructors, and students, with a focus on continuous improvement and adaptation of teaching strategies. By creating a more supportive and resource-rich learning environment, students can gain the skills necessary to succeed in engineering drawing and other related fields, ensuring a smoother transition into professional engineering careers.

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