

## Exploring Design Thinking Perception among First-Year Mechanical Engineering Students in a Design Course

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### ABSTRACT

*Design thinking is fundamental to engineering education, yet first-year students often face challenges, including design fixation, which limits creative problem-solving. This study investigates the perception of design thinking traits among first-year mechanical engineering students enrolled in the Introduction to Design course at a public university in Malaysia, aiming to identify factors influencing design thinking capabilities and strategies to overcome design fixation. A quantitative approach was employed using a questionnaire adapted from the Approaches and Study Skills Inventory for Students (ASSIST) and Design Thinking Traits (DTT) instruments. The survey, comprising 31 items with a 5-point Likert scale, was administered to 101 randomly selected first-year mechanical engineering undergraduates from 350 enrolled students across thirteen course sections. The instrument assessed five key constructs: Empathetic Engagement, Problem Sensing, Creative Risk Taking, Constructive Action, and Reflective Evaluation. Descriptive statistics were conducted using IBM SPSS Statistics 29 to examine relationships between design thinking perceptions and variables, including gender, former educational background, and technical proficiency in operating machines and tools. Results revealed generally positive perceptions across all constructs, with Reflective Evaluation scoring highest and Empathetic Engagement scoring lowest. These findings underscore the need for differentiated instructional strategies that cater to diverse educational backgrounds, incorporating defixation techniques, empathy-building activities, and hands-on skills development to cultivate adaptive, creative engineering problem solvers. This ongoing research agenda will continue to advance engineering education, ensuring that programs produce graduates equipped with both the technical competence and creative thinking capabilities necessary for innovative design practice.*

*Keywords: Engineering education; design thinking; design fixation; perception*

### INTRODUCTION

Design is often recognized as the core of engineering (Simon 1996). Design thinking functions as the analytic and creative process within this core, providing the specific strategies and iterative phases required to bridge the gap between a complex problem space and a functional design solution. Additionally, it has been suggested that engineering programs should produce graduates who are capable of developing effective solutions to address societal needs (Evans et al. 1990). Dym et al. (2005) argued that

engineering programs should produce graduates capable of designing effective solutions that address societal needs. However, Todd and Magleby (2004) noted that many design faculty believe engineering department leaders and institutions fail to recognize the intellectual complexity and resources required to support high-quality design education.

Visser (2006) refers to design thinking as creative strategies designers use during the process of designing. Ulla et al. (2013) noted that design thinking is a concept applied in both theoretical and practical contexts, and they predicted that its use in education would lead to varied

discussions and empirical studies employing diverse methodologies.

Design thinking can be conceptualized as an iterative, analytical, and creative process in which individuals engage in experimentation, prototyping, feedback gathering, and continuous refinement of ideas (Razzouk & Shute 2012). Acebo claimed that design thinking is not only a well-known technique for user-oriented product design, but also an educational technique in Higher Education (2021).

In engineering education, design thinking is commonly used across disciplines through project-based or problem-based learning of dedicated courses to promote human-centered innovation, creativity, and complex problem-solving. It also helps them understand how to use empathy, iterative prototyping, and societal context in the engineering design process.

Among the available design frameworks or models used in engineering is Stanford d.school (2015). This model outlines a six-phase design thinking process that students typically follow. The first phase, Understand, involves exploring the topic through research to build familiarity with the subject matter. This is followed by the Observe phase, where students pay attention to their environment, including physical settings and human interactions, to gain deeper insights into people's behaviors and motivations. In the Point of View phase, students consider alternative perspectives to better define the problem and guide idea generation.

The Ideate phase encourages students to brainstorm freely, focusing on creativity and generating a wide range of ideas without criticism. Subsequently, in the Prototype phase, students develop quick, low-fidelity prototypes to investigate the feasibility of selected ideas. Finally, the Test phase involves evaluating these prototypes to identify which aspects are effective and which require improvement.

Braha and Reich (2003) conceptualized the design process as a generic and iterative activity in which designers revise either the emerging design or its requirements and specifications in response to newly acquired information. This continuous refinement aims to resolve inconsistencies and achieve alignment between the problem space and the proposed design solution.

## ISSUES AND CHALLENGES IN DESIGN

Students in engineering education often face several challenges while working on design tasks assigned by lecturers. One of the problems faced by the students was Design Fixation. Design fixation refers to situations in which designers restrict their creativity due to excessive

reliance on features of existing designs or, more broadly, on a specific set of knowledge closely related to the problem (Youmans & Arciszewski, 2014).

Throughout the design thinking process, one of the frequently experienced challenges that students face is design fixation, as a result of becoming caught on the same idea or past knowledge during the design process. Design fixation is often used interchangeably to refer to situations where designers limit their creative output because of an overreliance on features of preexisting designs, or more generally, an overreliance on a specific body of knowledge directly associated with a problem (Youmans & Arciszewski 2014).

There are several factors that contribute to the challenges faced by students in engineering design. First, students often struggle with a lack of problem understanding, particularly when dealing with open-ended design problems that are ambiguous and difficult to interpret, which may result in confusion about requirements and constraints. Second, limited creativity and innovation can hinder progress, as many students tend to rely on conventional solutions and may avoid risk-taking due to fear of failure. Third, insufficient technical knowledge is a common issue, where students lack the necessary engineering principles, software skills, or hands-on experience to implement their ideas effectively, making it difficult to translate theoretical knowledge into practical applications.

Time management issues also frequently arise because design tasks require multiple iterations, and poor planning can lead to last-minute work and suboptimal solutions. In addition, collaboration and communication problems can occur in group projects when students face difficulties in coordinating tasks, leading to conflicts or unequal work distribution. Students may also struggle to communicate design ideas effectively through sketches, CAD models, or verbal explanations, which can impede the overall design process.

Furthermore, some students experience difficulty in using design tools and software, such as CAD programs, simulation tools, or prototyping equipment, and limited access to proper resources can further hinder progress. Balancing functionality with cost and feasibility presents another significant challenge, as students must consider budget constraints, material availability, and manufacturing limitations, which may lead to overly ambitious or impractical designs. Finally, students often find iterative thinking and prototyping challenging, as they may expect to achieve a perfect design on the first attempt and hesitate to test prototypes due to lack of confidence or fear of failure.

## RESEARCH OBJECTIVES

To address the issues in design thinking, it is essential to have an overview of design thinking in engineering students before suggesting any interventions or curriculum alignment to foster 21<sup>st</sup> century skills. The primary objective of this study is to investigate the perception of design thinking among first-year mechanical engineering students enrolled in the Introduction to Design course at a public university in Malaysia. Given the critical role of design thinking in developing innovative engineering solutions and the persistent challenge of design fixation that constrains creative problem-solving, this research seeks to provide empirical insights into how novice engineering students perceive and engage with design thinking processes.

Specifically, this study aims to assess the overall perception of design thinking traits among first-year mechanical engineering students, examine the relationship between students' former educational backgrounds, and also investigate the influence of technical proficiency in operating machines and tools on students' perception of design thinking capabilities.

## METHODOLOGY

### QUANTITATIVE STUDY

A quantitative study was carried out to investigate the perception of design thinking traits among first-year engineering students using a set of questionnaire. The questionnaire was adapted from Approaches and Study Skills Inventory for Students (ASSIST) (Entwistle & Tait, 2013) and Design Thinking Traits (DTT) (Blizzard et al. 2015).

The ASSIST questionnaire is designed to measure how students approach their studies and learning. It is based on research into learning strategies, particularly developed by Marton and Saljo in 1997 for the deep and surface learning model. The Deep Approach in ASSIST emphasizes conceptual understanding and meaning, is linked to intrinsic motivation and critical thinking, and involves strategies such as connecting ideas, analyzing arguments, and seeking deeper comprehension.

The Strategic Approach of ASSIST focuses on achieving high grades through organized and efficient study. Students monitor their progress, use time management, and respond effectively to assessment demands. The Surface Approach is characterized by rote memorization and minimal effort, often driven by extrinsic motivation and fear of failure, leading to passive learning

strategies such as cramming and reproducing information without deep understanding.

The study by Jacquelyn Blizzard et al. (2015) identified nine survey items that best represent DTT. These items were derived through exploratory factor analysis (EFA) and regression modeling, and correspond to five key characteristics of design thinking: collaboration, experimentalism, optimism, feedback-seeking, and integrative thinking. Therefore, based on the literature review that has been done, the constructs in design thinking traits that will be assessed in this study are particularly Empathetic Engagement, Problem Sensing, Creative Risk Taking, Constructive Action, and Reflective Evaluation.

### INTRODUCTION TO DESIGN COURSE

The Introduction to Design is a core course for first-year Mechanical Engineering students at the university. This course aims to equip students with fundamental design concepts and methods that enable the development of systematic design processes and their creative and effective application to engineering design problem-solving.

The course learning outcomes were designed to guide students through a complete design process. Students were expected to conduct a background study and develop product design specifications (PDS), followed by translating the design problem into multiple potential solutions. They were then required to evaluate these possible solutions and develop a final design. In addition, students were expected to construct and test a physical model, as well as deliver oral and written presentations on the final design. Finally, the course aimed to develop leadership and teamwork skills, with students taking responsibility as team leaders and collaborating effectively to solve the design problem.

### STATISTICAL ANALYSIS

The survey was conducted among 101 first-year mechanical engineering undergraduates who were enrolled in this course. The respondents were randomly selected from 350 enrolled students from thirteen (13) different sections that are taught by different instructors.

This instrument was used to measure individuals' rate on design thinking using 31 items adapted from ASSIST and DTT. The questionnaire used a 5-point Likert scale (1- Strongly Disagree, 2- Disagree, 3- Not Sure, 4- Agree, 5- Strongly Agree), which assessed Empathetic Engagement, Problem Sensing, Creative Risk Taking, Constructive Action, and Reflective Evaluation. The internal consistency of the instrument was assessed using Cronbach's alpha. A value of 0.70 or higher was considered acceptable for this

study (Nunnally & Bernstein, 1994; George & Mallery, 2003). The Cronbach's Alpha reliability coefficient for the constructs is ( $\alpha = 0.795$ ).

All statistical analyses were performed using IBM SPSS Statistics 29. The internal consistency of the items representing each learning style was assessed using Cronbach's alpha. For each respondent, mean scores were computed for each design thinking trait. These scores were then compared using one-way analysis of variance (ANOVA) based on respondents' prior educational background and their ability to use machines and tools. The comparisons were made between the mean score of design thinking traits. The questionnaire designed for this study was based on the constructs extracted from the literature as summarized in Table 1.

TABLE 1. Constructs measured and relevant adaptation

Constructs	Reference (s)	Number of items
Empathetic Engagement	ASSIST and DTT	5
Problem Sensing	ASSIST and DTT	6
Creative Risk Taking	ASSIST and DTT	6
Constructive Action	DTT	7
Reflective Evaluation	DTT	7

## RESULTS AND DISCUSSION

### ASSESSING PERCEPTION ON DESIGN THINKING TRAITS

Completed questionnaire forms were returned by 101 students. The demographic composition consisted of 44 female respondents (43.6%) and 57 male respondents (56.4%), providing a reasonably balanced gender representation for analysis. As shown in Table 2, the analysis of design thinking traits revealed nuanced patterns in students' perceptions across the five key constructs. The dominant design thinking trait recorded by the students was Reflective Evaluation, with a mean score (SD) of 4.04 (0.387), followed closely by Problem Sensing at 4.02 (0.389). Creative Risk Taking demonstrated a mean score of 4.01 (0.463), while Constructive Action scored 3.99 (0.418). Notably, the lowest score was observed in Empathetic Engagement, with a mean score (SD) of 3.93 (0.369).

TABLE 2. Mean and standard deviation values for first-year students' design thinking perception

Design Thinking Traits	Mean	Std. Deviation
Empathetic Engagement	3.93	.369
Problem Sensing	4.02	.389
Creative Risk Taking	4.01	.463
Constructive Action	3.99	.418
Reflective Evaluation	4.04	.387

The relatively high scores across all constructs (ranging from 3.93 to 4.04 on a 5-point scale) indicate that students generally possess positive perceptions of their design thinking capabilities. However, the standard deviations reveal important variations in individual responses, with Creative Risk Taking showing the highest variability ( $SD = 0.463$ ), suggesting that students have diverse confidence levels regarding their willingness to take creative risks and explore unconventional solutions.

The prominence of Reflective Evaluation as the highest-rated trait suggests that first-year students recognize the importance of analyzing and learning from their design experiences. This metacognitive awareness is encouraging, as it indicates students' readiness to engage in iterative improvement processes. The strong showing in Problem Sensing (4.02) demonstrates that students feel confident in their ability to identify and frame design challenges, which is a fundamental prerequisite for effective design thinking.

This may be due to their limited exposure to these processes. The positive perception of design thinking traits among first-year students may be attributed to what the Introduction to Design course initially framed, preconceived notions about engineering problem solving, and their limited exposure to design methodologies.

While early work by Badke-Schaub and Fricke (1999) described successful designers as those who clarify requirements, seek information, and iteratively refine solutions, more recent research in design thinking continues to underscore the iterative, adaptive nature of the design process. For example, Bender-Salazar et al. (2023) highlight the role of need finding and double-loop learning in shaping design actions, and Ardila Echeverry et al. (2025) demonstrate how iterative engagement with complex challenges fosters design competence in higher education contexts.

These results collectively demonstrate that the Introduction to Design course succeeds in preparing first-year engineering students to understand the fundamental aspects of the design process. However, the variations across constructs highlight specific areas where additional pedagogical interventions could enhance students' design thinking capabilities. The positive perception of design thinking traits among first-year students may be attributed to several factors: the foundational framework established by the Introduction to Design course, students' preconceived notions about engineering problem-solving shaped by their secondary education, and their enthusiasm as newcomers to engineering education.

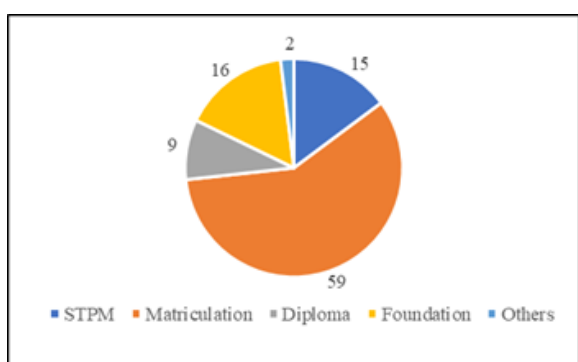


FIGURE 1. Number of respondents based on their former educational background

### ANALYSIS OF FORMER EDUCATION BACKGROUND

Further analysis was carried out to identify the relation between design thinking traits and the former educational background of respondents. The number of respondents based on their former educational background is shown in Figure 1. The results in Figure 2 show a statistically significant difference in first-year students' perception of

design thinking based on their former education background, which includes STPM, Matriculation, Diploma, Foundation, and others. The results presented in Figure 2 demonstrate compelling patterns across the five design thinking constructs. Most notably, students from Matriculation backgrounds consistently scored higher across multiple dimensions, particularly in Creative Risk Taking. This elevated performance in Creative Risk Taking is especially significant, as it indicates a more open and exploratory mindset characterized by a willingness to propose diverse ideas, experiment with unconventional approaches, and embrace uncertainty in the design process.

The superior performance of Matriculation students can be attributed to several factors inherent in the Matriculation system's pedagogical approach. Matriculation programs typically emphasize broad-based learning, critical thinking, and problem-solving across multiple disciplines. Students in these programs are often encouraged to approach problems from multiple perspectives and are less constrained by specialized technical knowledge. This educational philosophy appears to foster what can be characterized as "novice flexibility", a cognitive advantage where limited prior exposure to specific design conventions allows for more creative and uninhibited ideation.

Matriculation students typically exhibit novice behavior associated with a depth-first approach to problem-solving, wherein they identify and explore sub-solutions in depth and sequentially. Importantly, they demonstrate flexibility in changing goals and constraints as they design, readily adapting their approach when faced with new information or challenges. This adaptability is crucial in design thinking, where iteration and refinement are essential processes. Their willingness to select and try different solutions without being anchored to previous experiences enables them to generate more diverse and innovative design alternatives.

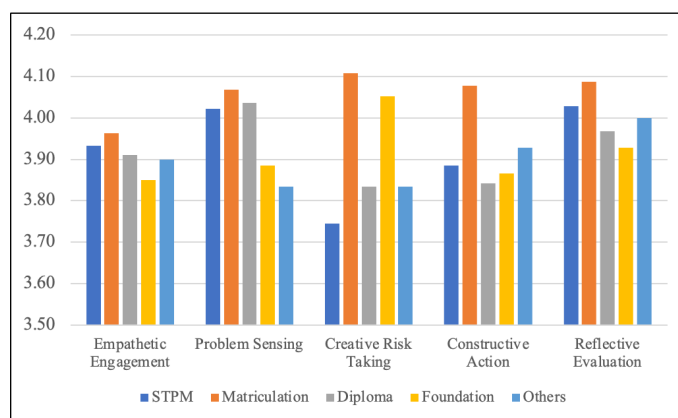


FIGURE 2. Bar chart of the mean score and former educational background

In contrast, respondents with former educational backgrounds in Diploma and Foundation programs demonstrated a different pattern of engagement with design tasks. These students, having already accumulated specific experiences related to particular problem types, tended to approach design tasks through solution assumptions and conjectures rather than thorough problem analysis. This observation aligns with the design fixation literature, which suggests that prior experience with specific problem types can lead designers to perceive design problems primarily in terms of solutions they have previously encountered.

This phenomenon represents a classic manifestation of design fixation occurring at the early stages of the design process. Students with Diploma backgrounds, in particular, often bring substantial technical knowledge and hands-on experience with engineering systems and components. While this expertise is valuable in many contexts, it can paradoxically constrain creative thinking by biasing students toward familiar solutions. These students may prematurely converge on known solutions without adequately exploring the problem space or considering alternative approaches.

Foundation program students, who typically spend an additional year bridging from secondary education to university-level engineering studies, showed intermediate patterns. Their longer exposure to engineering concepts and problem-solving methods provided them with valuable technical foundations but also potentially introduced biases toward conventional approaches. The data suggest that these students may benefit from explicit instruction in divergent thinking techniques and strategies to overcome functional fixedness.

The result aligns with Rowe (1987), who argued that the direction of designers' problem-solving is heavily guided by their early design concepts, which in turn are informed by previous experience and existing knowledge. The relationship between prior knowledge and design fixation represents a paradoxical challenge in engineering education. While experience and technical expertise are essential for effective design, they can simultaneously limit creative exploration if not balanced with strategies to promote divergent thinking.

The implications for curriculum design are substantial. Educators should recognize that students entering from different educational backgrounds bring distinct cognitive strengths and limitations to the design process. Matriculation students may require additional support in developing technical skills and domain-specific knowledge. In contrast, Diploma and Foundation students may benefit from interventions designed to promote cognitive flexibility and overcome design fixation. Possible pedagogical strategies include: providing defixation interventions such as exposure to analogies from distant domains, implementing

structured brainstorming techniques that explicitly defer judgment, encouraging systematic exploration of the problem space before solution generation, and creating diverse student teams that combine novice flexibility with technical expertise.

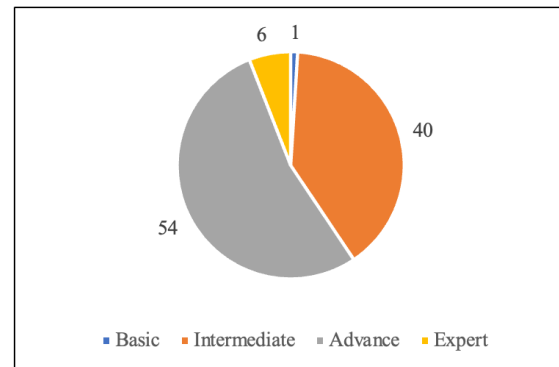


FIGURE 3. Number of respondents based on their ability to operate machines and tools

#### ABILITY IN OPERATING MACHINES AND TOOLS

The analysis of factors related to ability in operating machines and tools will also be reported. Figure 3 presents the distribution of respondents based on their responses, which were originally measured on a 10-point scale and subsequently categorized into four distinct proficiency levels for analytical purposes.

The skill categorization system was designed to maintain clear distinctions while simplifying analysis: 'Basic' level (corresponding to scale values 1 to 3) represents limited ability to use machines and tools, indicating minimal hands-on experience; 'Intermediate' level (values 4 to 6) represents moderate ability with some proficiency, suggesting familiarity with common tools but limited advanced capabilities; 'Advanced' level (values 7 to 8) represents high skill level with strong competence, indicating substantial practical experience and confidence in using various equipment; and 'Expert' level (values 9 to 10) represents very high or mastery-level proficiency, suggesting extensive hands-on experience and the ability to handle complex equipment independently.

Conversely, students at Basic and Intermediate skill levels faced substantial challenges in the prototype and test phases of the design process. These students had to invest considerably more time in several areas: Learning to operate equipment and tools, which consumed time that could otherwise be devoted to design iteration. Seeking assistance from instructors, teaching assistants, or peers, they created dependencies that slowed their progress. Overcoming uncertainty and building confidence in their technical abilities, which sometimes led to risk-averse

design choices. Troubleshooting unexpected problems due to their limited experience with how materials and components behave in practice. The relationship between technical proficiency and design thinking traits also highlights the multidimensional nature of design competence. While Creative Risk Taking and Problem Sensing may be less dependent on hands-on skills, Constructive Action shows that the ability to translate ideas into tangible prototypes is clearly influenced by technical proficiency. This finding reinforces the importance of integrating practical skills development with conceptual design thinking instruction in engineering curricula.

Figure 4 illustrates the nuanced relationship between technical ability and design thinking trait scores across the

five constructs. While students at all skill levels demonstrated positive perceptions of their design thinking capabilities, those with Advanced and Expert proficiency showed particular strength in Constructive Action, consistent with their superior prototyping abilities. Interestingly, Creative Risk-Taking scores showed less variation across skill levels, suggesting that willingness to explore unconventional ideas is somewhat independent of technical proficiency, a finding that emphasizes the importance of fostering creative confidence regardless of students' hands-on experience. The iterative process of design allows students to accept ambiguity and explore imperfect responses, aligning with Piaget's perspective on progressive knowledge construction (Kijima et al. 2021).

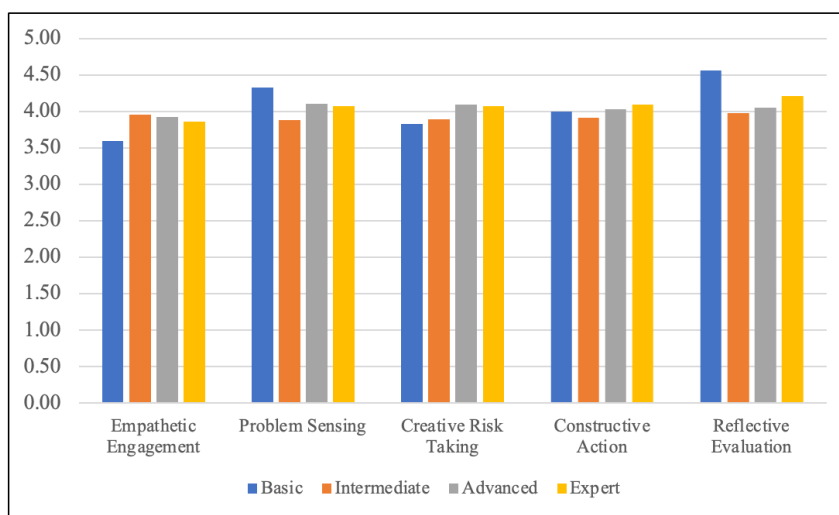


FIGURE 4. Bar chart of mean score and ability on handling machines and tools

## CONCLUSION

The study provides initial insights into the perception of design thinking among first-year mechanical engineering students. The findings suggest that while students have a positive general perception, their former educational background significantly influences their understanding and approach to design thinking. This highlights the need for educators to be mindful of the diverse learning experiences students bring to the classroom and to implement strategies that address potential biases or limitations.

The examination of former educational backgrounds revealed statistically significant differences in design thinking perceptions, with particularly notable implications for addressing design fixation. Matriculation students demonstrated superior performance in Creative Risk Taking, exhibiting greater openness to explore diverse

solutions and experimenting with unconventional approaches. This advantage appears to stem from their relative lack of specialized prior knowledge, enabling what might be termed cognitive flexibility through limited exposure.

In contrast, students from Diploma and Foundation backgrounds, despite possessing valuable technical knowledge and practical experience, showed tendencies toward solution-focused approaches rather than comprehensive problem analysis. These students appeared more susceptible to design fixation, prematurely converging on familiar solutions based on prior experiences rather than thoroughly exploring the problem space. This finding underscores a fundamental paradox in engineering education: while expertise and experience are essential, they can simultaneously constrain creative thinking if not accompanied by explicit strategies to promote divergent thinking and overcome functional fixedness.

The analysis of technical proficiency in operating machines and tools revealed another crucial dimension influencing design thinking implementation. Students with advanced hands-on skills demonstrated significantly greater efficiency in prototyping and testing phases, enabling more rapid iteration cycles and allowing for exploration of multiple design alternatives. In contrast, students with basic to intermediate skill levels invested considerably more time in learning to operate equipment and translating concepts into physical prototypes, reducing their capacity for iterative refinement. This finding highlights the importance of integrating practical skills development with conceptual design instruction, ensuring that all students possess sufficient technical capabilities to meaningfully participate in hands-on design activities.

As described earlier in the research objectives, Razzouk and Shute (2012) suggested that students' design thinking abilities can be enhanced by integrating authentic and engaging tasks into classroom activities, providing repeated opportunities to apply design processes while avoiding design fixation. Strong design thinking skills also support the ability to solve complex problems and adapt to unforeseen changes. Effective design processes support creative exploration, iteration, and refinement of solutions of principles that align with the idea of clarifying and modifying requirements through continuous information gathering and feedback (Sreenivasan, 2024).

Future research should extend this investigation to explore educators' perspectives on students' design thinking processes and systematically document the occurrence and mitigation of design fixation across different pedagogical approaches. Longitudinal studies tracking students' development throughout their engineering programs would provide valuable insights into how design thinking capabilities evolve with increasing expertise and whether early interventions successfully prevent design fixation in later years.

Additionally, experimental studies comparing different instructional strategies for promoting cognitive flexibility among students with varying educational backgrounds would help refine evidence-based teaching practices. This ongoing research agenda will continue to advance engineering education, ensuring that programmes produce graduates equipped with both the technical competence and creative thinking capabilities necessary for innovative design practice.

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#### DECLARATION OF COMPETING INTEREST

None.

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