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Assessment of Competencies and Capabilities of Spatial Design Thinking among Students in Higher Education Universities in Malaysia

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Abstract

Design thinking in design education has been observed to enhance understanding of design direction and has gained nationwide recognition. Its usage among industrial design students in design schools could improve teaching methods and strengthen students' design capabilities. Spatial ability within design thinking gave the Industrial design student the knowledge to expand comprehension towards design projects at early stages. This study uses survey research to examine 102 industrial design students' spatial design thinking skills, such as visualising, imagining, and reasoning, in Malaysian higher education institutions. This study found that incremental spatial ability improves students' comprehension of design activities. This study demonstrates the efficacy of design thinking in enhancing students' ability to identify and resolve design challenges.

Keywords: Design Thinking, Spatial Design Thinking, Industrial Design Student, Skills

Introduction

Spatial design thinking, originating in architecture through figures like Frank Lloyd Wright and Le Corbusier, has evolved into industrial design, product design, and engineering (Carrera et al., 2020). This evolution was influenced by the ground-breaking ideas on human cognition and problem-solving introduced by Herbert Simon and George Miller in the 1950s and 1960s (Atman et al., 2007). The application of spatial design thinking gained traction in the corporate world during the 1970s and 1980s to address challenges and drive innovation (Atman et al., 2007). Tom and David Kelley, consultants, have further advanced problem-solving and innovation techniques rooted in spatial design thinking, enabling companies to develop innovative products and services that meet customer needs (Atman et al., 2007).

Spatial thinking, a key component of spatial design thinking, involves understanding size, shape, location, direction, navigation, map usage, object transformation, and pattern creation

(Garcia et al., 2022). This type of thinking is crucial in various fields, including science, technology, engineering, and mathematics (STEM) (DeSutter & Stieff, 2017). Studies have shown a strong correlation between spatial thinking skills and advancements in STEM disciplines, emphasising its importance in educational settings (Belavina, 2021).

Design thinking, a human-centred approach that prioritises understanding user needs, has gained significant attention across different sectors beyond traditional design realms (Kimbell, 2011). It has become a popular methodology for addressing complex, "wicked problems" in a user-centric manner (Hehn et al., 2020). The design thinking process typically involves three main phases: inspiration, ideation, and implementation, supported by various strategies to foster innovation (Wolcott & McLaughlin, 2020).

Applying spatial design thinking in learning environments can significantly enhance their functionality, making classrooms more adaptable and versatile (Liedtka, 2014). This approach empowers students to engage in hands-on projects, allowing them to assess and improve their spatial cognition and problem-solving skills (Aflatoony et al., 2017). In industrial design, strategic planning, product development, and interdisciplinary collaboration are crucial aspects that must be prioritised (Cook & Bush, 2018). Despite significant progress in industrial design, design education often focuses more on aesthetics and form conceptualisation (Allsop, 2019). To address this gap, architecture, engineering, design, and business students should cultivate human-centred spatial design thinking, utilising spatial logic, creativity, and critical thinking (Henriksen et al., 2017).

Design thinking, a human-centred problem-solving approach, has gained prominence in various educational contexts, emphasising pedagogical methods like problem-based and project-based learning to develop design thinking skills (Carroll, 2014). Design thinking encourages students to redefine and reimagine solutions to complex problems creatively, mirroring the professional skills of designers (Hou et al., 2014). By infusing design thinking principles into learning environments, educators can effectively teach the fundamental mindsets and processes of design thinking while integrating content learning (DeSutter & Stieff, 2017). Moreover, using spatial thinking skills, such as spatial orientation and visualisation, contributes to early mathematical thinking and should be integrated into educational practices (Grau & Rockett, 2022).

Enhancing spatial thinking skills and learning outcomes is essential for students to thrive in a competitive global landscape (Banter et al., 2020). Incorporating spatial intelligence into geography learning through problem-based hybrid learning models can improve students' sensitivity to their environment and enhance their spatial thinking abilities (Xiang & Liu, 2018). Studies have shown that applying design thinking in learning environments yields numerous benefits, contributing to effective educational interventions and theory development (Bodzin, 2010). By creating technology-enhanced learning environments that stimulate different modes of thinking and visualisation techniques, students can develop abstract thinking skills and engage in higher-order thinking processes (Pritulsky et al., 2020).

Background

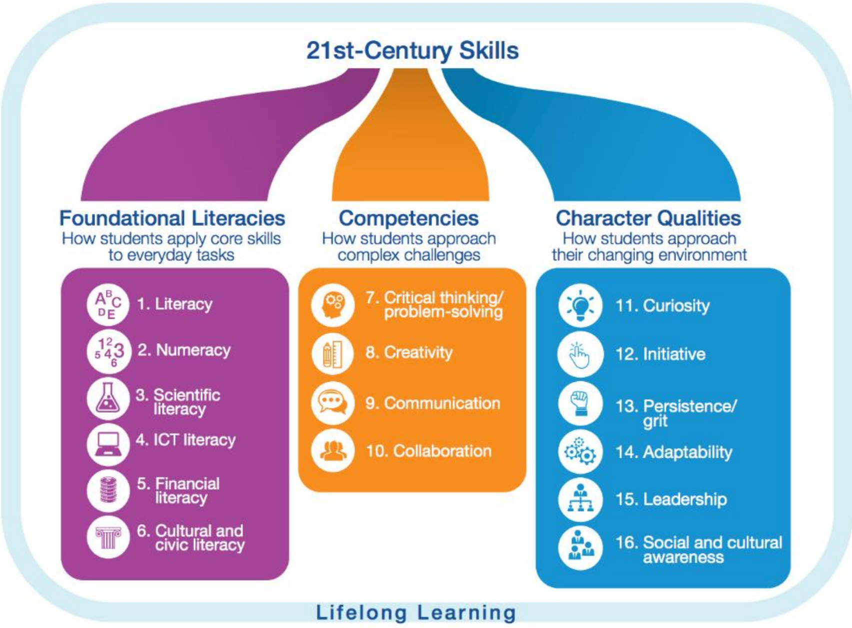
Design Education, in General

To meet the demands of a rapidly changing economy, industrial design education in the UK should adapt to focus on emerging technologies and interdisciplinary skills. While traditional emphasis has been on mechanical engineering and computer-aided design (CAD), there is a growing need for expertise in areas such as data analysis, artificial intelligence (AI), and user experience (UX) design Zhu (2024). Modern engineers must have essential skills to address ambiguous problems, bridge diverse fields, communicate effectively, and handle non-technical issues (Frey & Osborne, 2017). Integrating engineering design into mechanical engineering courses can give students a deeper understanding of complexity and the interconnectedness of various disciplines (Wallisch et al., 2019).

Integrating artificial intelligence (AI) in education has introduced innovative educational models and products like intelligent classrooms and personalised learning systems (Dai, 2021). This deep integration has led to significant changes in educational patterns, highlighting the importance of intelligent education tailored to individual needs and learning styles ("Research on Undergraduate Vocational Education Talent Training Based on the Deep Integration of Artificial Intelligence and Education", 2023). AI technologies, such as intelligent tutoring systems, have the potential to enhance transdisciplinary problem-solving in design-led integrated STEM education, showcasing AI's capacity to revolutionise educational approaches (Zhou et al., 2023).

In the digital era, design education must leverage opportunities presented by artificial intelligence and big data (Hao, 2022). By incorporating AI-based tools and platforms, educators can enhance teaching methods, offer personalised learning experiences, and improve the effectiveness of educational interventions (Zhao & Fu, 2022). AI in higher education can automate administrative tasks, provide personalised learning experiences, and support students inside and outside the classroom (Hinojo-Lucena et al., 2019). Furthermore, integrating AI in music education systems and physical education teaching can lead to more intelligent and personalised learning experiences (Yang & Wang, 2020; Zhang & Yang, 2021).

Exhibit 1: Students require 16 skills for the 21st century



Note: ICT stands for information and communications technology.

Figure 1: 21st Century Skills

Educational institutions must adapt their courses and teaching methods to meet the demands of the rapidly evolving digital economy and cater to modern learning preferences. The World Economic Forum highlights the importance of students acquiring skills beyond academic education to excel in today's dynamic professional landscape Dym et al. (2005). Social and Emotional Learning (SEL) equips students with the necessary skills for success, encompassing academic education and essential socio-emotional competencies (Umutlu, 2022). Therefore, universities should exhibit creativity and dynamism by integrating design thinking into general education in the 21st century (Glen et al., 2015).

As a problem-solving approach, design thinking signifies a shift in education towards more active, problem-based learning methods (Razali et al., 2022). It has been acknowledged as a valuable tool for enhancing the teaching and learning process, particularly in fostering 21st-century skills among students (Nielsen & Stovang, 2015). By incorporating design thinking into education, students can develop diverse interdisciplinary skills and enhance their problem-solving abilities (Amalia & Korflesch, 2022). This approach nurtures creativity and equips students with the tools to address complex, real-world challenges (Kian, 2022).

The infusion of technology-driven design thinking in industrial design education has revitalised curricula and enriched students' learning experiences (Mubin et al., 2017). By integrating design thinking principles into educational frameworks, students can cultivate innovative digital technology design skills, fostering creativity and problem-solving abilities (Wang et al., 2021). Furthermore, the creative amalgamation of design and strategic thinking is imperative for designers to navigate complexity and uncertainty in an era of constant transformation (Danchenko, 2021).

Design Education in Malaysia Context

Lim (2015) highlights the importance of education providers actively assessing and developing strategies to enhance design thinking competency within their curriculum. It aligns with the notion that top colleges are offering public educational materials to support the development of design skills, particularly in countries like Singapore and Malaysia, where there is a focus on preparing students to navigate diverse scenarios effectively (Miles et al., 2012). Designers are urged to respond to the evolving needs of the creative industry by creating design outputs that not only showcase creativity but also have the potential to evolve into profitable brands. Research by Basyarah Hamat, Boris Eisenbart, and Jan Schoormans emphasises the significance of discerning and opportunistic mindsets in design education. Students with a sensible perspective tend to generate high-quality design ideas, while those with an opportunistic mindset may provide less effective solutions (Hilton, 2016). Therefore, the effects of design education on students' mindsets and outcomes must be carefully evaluated to ensure optimal learning experiences and skill development.

Incorporating design thinking into education can foster a problem-solving approach that enhances students' creativity, critical thinking, and interdisciplinary skills (Steffener et al., 2016). This shift towards active, problem-based learning methods is essential for nurturing 21st-century skills among students and preparing them for the demands of the modern workforce (Evans & Schwab, 1995). By integrating design thinking principles into educational frameworks, institutions can empower students to address complex challenges and develop innovative solutions (Cellini, 2009).

Spatial Ability in Design Education

Education in design, namely in interior and garment design, has a significant impact on developing spatial intelligence, which is vital for problem-solving and improving design proficiency (Sung et al., 2018). Studies indicate that spatial aptitude is a reliable indicator of a person's ability to excel in educational and occupational pursuits. This ability can significantly assist students in making informed decisions about their academic and career paths (Sung et al., 2018). Moreover, there is a correlation between spatial competence and design innovation, and improving spatial ability can assist students in cultivating and generating new ideas (Burgaleta et al., 2013). It emphasises the importance of spatial intelligence in design education and its ability to enhance creative thinking in design.

Educators can promote the development of spatial awareness by instructing students in visualisation techniques and improving their ability to convert 2D images into 3D representations mentally. These skills are fundamental to spatial thinking (Jung et al., 2015). Furthermore, researchers have examined the correlation between occupational ability and interest in university students, highlighting the essential importance of these elements in assisting students when making career decisions (Fatuhrahmah et al., 2020). Hence, it is imperative to promote the cultivation of visualisation and spatial cognition in design education, as it plays a vital role in improving spatial ability and ultimately making significant contributions to STEM achievement, namely in interior and garment design.

Definition of Spatial Design Thinking

There are various definitions and viewpoints about spatial design thinking. According to Micheli et al. (2018), Brown's Design thinking achieves consumer value and market potential by effectively reconciling the requirements of individuals with the technological viability and long-term profitability of a corporation. This definition combines design with business by emphasising the technique and characteristics of design thinking. Dell'Era et al. (2020) define design thinking as generating ideas, creating prototypes, involving stakeholders, and evaluating and analysing the results. These design thinking methodologies encompass the entire process, from ideation implementation to assessment. This perspective showcases the intricate nature of design thought.

According to Pritulsky et al (2020), preschool-aged children require spatial thinking skills. Engaging in spatial thinking aids children in acquiring knowledge of mathematics, numerical concepts, shapes, and spatial abilities. Early childhood learning promotes the development of spatial thinking. Alternative terms for spatial thinking are spatial literacy, aptitude, intelligence, and geographical reasoning (Trifunović Peand trašević, 2021). It signifies that spatial thinking exhibits various variations and can be treated from several perspectives. Multiple definitions and viewpoints on spatial design thinking can be found here. A multidimensional concept utilises design principles and methodologies to tackle issues and fulfil individuals' requirements, considering technological advancements and financial considerations. Designs require spatial reasoning, the foundation for mathematical and spatial abilities.

Component of Spatial Design Thinking

This article applies Maier's (1994) notion of spatial intelligence, which includes spatial perception, visualisation, mental rotation, connection, and orientation. To classify Spatial Ability, Maier examined and summarised structural ideas. It focused on Thurstone's (1950), and Linn and Peterson's (1985) category systems. The author outlines five elements: Even with external stimuli, spatial perception tests recognise horizontal or vertical orientation. Visualisation involves imagining a moving structure. With a wheel, mental rotation manipulates two- or three-dimensional objects fast and precisely. Spatial relation is the cognitive ability to perceive objects and components of spatial arrangement and relationships. An individual's spatial orientation is their ability to organise themselves.

Spatial perception is a crucial cognitive process that involves identifying and assessing an object's spatial arrangement and interaction. Cognitive processes need to be dynamic, and spatial orientation is necessary. Maier and K.Weigand et al. (2018) and Maier (1994, 1998) emphasise the importance of spatial skills in educational design, as they can be applied beyond geometry to industrial design. Spatial skills are essential for learning addition and subtraction, and they are also crucial for students' procedural representations, as they are spatially related. Despite changes in person-object interactions, spatial relationships remain stable, highlighting the need for dynamic cognitive processes and spatial skills in various aspects of life.

Spatial Visualising

Ewenstein and Whyte (2009), state that industrial designers employ visualisation to conceptualise objects and environments. Industrial designers must visualise concepts before drafting or prototyping. Graphical representations assist designers in evaluating the viability and user demands of new products. Practises of designing knowledge utilising epistemic

objects such as visualisations. These visual representations aid designers in communicating their ideas. Designers use visuals to comprehend the design issue and possible solutions.
Post-mission reviews in fast-jet fighter pilot simulators employ the utilisation of visualisation techniques. These concepts aid individuals in comprehending crucial information, reducing cognitive burden, and constraining potential interpretations. The evaluation and analysis of significant occurrences have a positive impact on the proficiency of pilots. (Aronsson et al., 2019). In social cognition, represent and infer others' mental states. The theory of mind hypothesis claims that we can assign mental states to others. This skill helps designers envision goods based on users' needs, interests, and viewpoints (Deschrijver & Palmer, 2020). Design challenges the mind. Imagine and change images to evaluate design decisions. Mental simulation has many approaches but similarities. Mental stimulation aids in design learning, innovation, and improvement (Christensen & Schunn, 2009).

Industrial designers need visualisation skills to build and manipulate mental images of products and scenes. Epistemic objects like visuals enhance knowledge acquisition and communication. Designers understand design difficulties and solutions with visualisation. Inferring mental states is necessary to design for user preferences. Mental simulation enables designers to evaluate designs. Visualisation helps industrial designers better their ideas before drawing or creating prototypes.

Spatial Imagining

Innovation is critical in industrial design. Industrial designers must imagine and construct new products to address problems or meet wants. The cognitive process of imagery—imagining non-existent objects or scenarios—is essential. Lawson (2006) says designers change mental representations and think differently. This creative knowledge method allows designers to experiment and produce distinctive designs. Before creating prototypes, industrial designers can visualise and manipulate design concepts to evaluate their practicality, functionality, and aesthetics.

Dorst (2011), emphasises industrial designer innovation through design thinking. Design thinking generates and explores ideas and perspectives via mental images. Industrial designers can solve problems creatively by examining design possibilities. Hatchuel and Weil's (2009) C-K design theory promotes mental images. This theory claims that designers originate and explore design concepts via mental imagery. Designers can experiment and expand their space. Simon (1996) defines design as producing and evaluating alternatives. Designers must mentally reproduce and envisage several design choices to assess their potential. Evaluating these choices helps industrial designers find the most excellent and creative solutions.

Finally, industrial designers require images to design. Designers may imagine non-existent items or circumstances to explore design possibilities. Industrial designers can mentally visualise and modify design concepts to evaluate feasibility, practicality, and aesthetics before producing prototypes. Design thinking and theory show how industrial designers use mental imagery to solve complex problems.

Spatial Reasoning

Spatial thinking explains spatial relationships and groupings. It helps industrial designers envision ideas practically. Industrial designers employ spatial reasoning to imagine a new car in a parking lot or a chair from multiple angles. Designers can assess feasibility, ergonomics, and aesthetics by mentally moving and arranging objects.

Different spatial perception, cognition, and mental manipulation abilities significantly impact spatial thinking. In some brains, spatial abilities let people comprehend and use items. Spatial skills increase with practice. Spatial thinking requires visuospatial reasoning—changing visual perceptions of things or scenes—according to Tversky (2005). Designers can test ideas by mentally rotating, scaling, and rearranging. The contextual function-behavior-structure framework by Gero and Kannengiesser (2004) describes spatial design thinking. This paradigm links design functional needs, behaviours, and structural features. Spatial thinking helps designers visualise how these parts fit. Cross (2011) defined design thinking as holistic, iterative problem-solving. Visualisation allows designers to create and explore spatial designs. Mentally positioning objects helps designers evaluate fit, form, and function.

Industrial designers must think spatially. Designers can visualise their ideas by evaluating spatial layouts and linkages. Visuospatial reasoning allows designers to alter object images cognitively. Design feasibility, ergonomics, and aesthetics depend on seeing and using goods in space. The contextual function-behaviour-structure framework and design thinking explain spatial design thinking. Spatial talents enhance designers' spatial ideas and designs.

Design Thinking in Design Education

Sutton and Williams study spatial abilities and design thinking. First-year design students are assessed on spatial ability based on gender, university admission score, and graphics course achievement. Spatial performance was weakly correlated with university entry scores, although findings varied. Top UAI students did poorly on the 3DAT, showing they may need better spatial skills and vice versa.

Multiple disciplines are needed to prepare pupils for current problems. Critical thinking, problem-solving, engineering, business, and psychology are taught in design thinking. User-centred design, marketing, entrepreneurship, and legality must be emphasised in design education. Participating in design hackathons and internships may help. Accepting variety and variance is essential for good design. This approach should include skills like drawing, sketching, and typography, incorporating marketing, entrepreneurship, and law. Therefore, design schools must offer scholarships, financial support, and an inclusive workplace to attract diverse students and staff. The cost of design education limits student access. Design education might be cheaper with scholarships, grants, and online courses. Empathy, ideation, prototyping, and evaluation develop creative ideas in human-centred design thinking. Design thinking may boost academic performance, solve classroom challenges, and create new educational materials. It can also help youngsters learn responsibility, critical thinking, problem-solving, creativity, invention, cooperation, and a growth mentality. Design thinking boosts education and job prospects. Design thinking was applied to build a primary school mathematical game prototype, disabled student software, and an economically disadvantaged college student programme. Design thinking can make design education more accessible and effective for all students.

Design Process in Education

Industrial design is a structured methodology to create products with functionality, aesthetic appeal, and user-friendliness. The iterative process involves information collection, idea generation, prototype creation, and testing. The design begins by understanding user requirements and contextual factors influencing product usage. Ideas are generated through free-thinking, creative exploration, brainstorming, and prototyping. Prototypes are developed to evaluate the functionality and efficacy of conceptual designs. User testing is conducted to ensure product alignment with users' needs. Refinement involves improving or enhancing the prototypes based on feedback from testing. Production involves creating goods or services through various inputs and activities, starting after the design is finalised and approved.

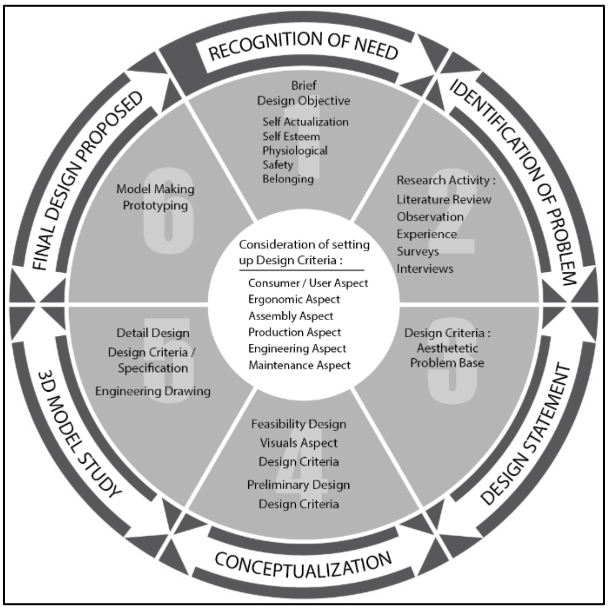


Figure 2: Design Process Wheel

The Double Diamond design process is a proven problem-solving and ideation tool. The four steps are Discovery, Definition, Development, and Delivery. Discovery deepens comprehension of the situation. Problems are refined and specified throughout the definition. The development phase involves the generation of concepts and prototypes. Ultimately, the solution will undergo delivery tests and be implemented. This design strategy works in business, education, healthcare, and government. The iterative method uses empathy mapping, issue statements, brainstorming, drawing, prototyping, and testing, which may necessitate revisiting some phases to develop the solution. Anyone looking to improve their problem-solving skills should use the Double Diamond design method.

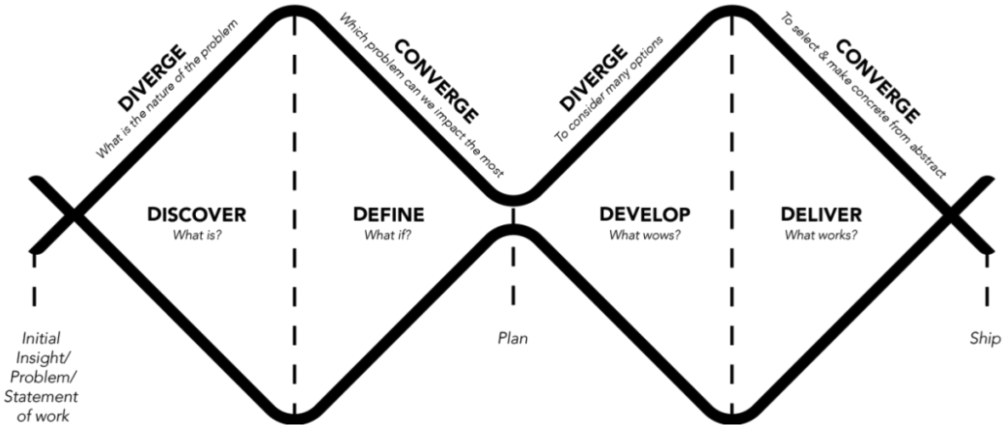


Figure 3: The Double Diamond

History of Design Thinking

The history of design has been studied in different ways. Design innovation and problem-solving are examined (Dorst & Cross, 2001). Protocol studies assessed experienced industrial designers' innovation and quality. This study emphasises creative problem-solving and iterative design. Education design theories are another issue. Universal Design for Learning (UDL) promotes accessibility to instructional technology using universal architecture (Rieber & Estes, 2017). It shows how different disciplines affected design theories and practices. Design-based research inspired 21st-century history instruction (Sebbowa &Ng'ambi, 2020). It involves honouring tradition and discourse, connecting the past to the present, and verifying historical knowledge. This study stresses modern learners' preferences in education. Reorganising design has improved efficiency. A co-evolution paradigm unites design fluidity goals, methodologies, and manifestations (Storm et al., 2019). It promotes design iteration and solution adaption.

Understanding the Evolution of Design Artefacts Frameworks, as described by Cristóbal et al. (2018), serves to structure and facilitate educational content development. They take into account every aspect, from abstract ideas to tangible goods. Multidisciplinary design history includes clothing, textile, garment, and product design (Bye, 2010). Each field uses design differently to create functional, unique solutions. The design process has evolved. Problem-solving and creativity evolve, design concepts are applied to various fields, educational standards are created, and design is rethought. These studies emphasise that knowing the history and evolution of design processes guides contemporary practices and innovation.

Research Problem

Spatial design thinking is crucial in industrial design education, and research-related studies can improve studio-based learning. A multidisciplinary approach, online studios, and augmented design studios are essential. Effective communication, practical experiences, technology integration, and critical thinking are crucial for industrial design students in Malaysia, preparing them for industry challenges.

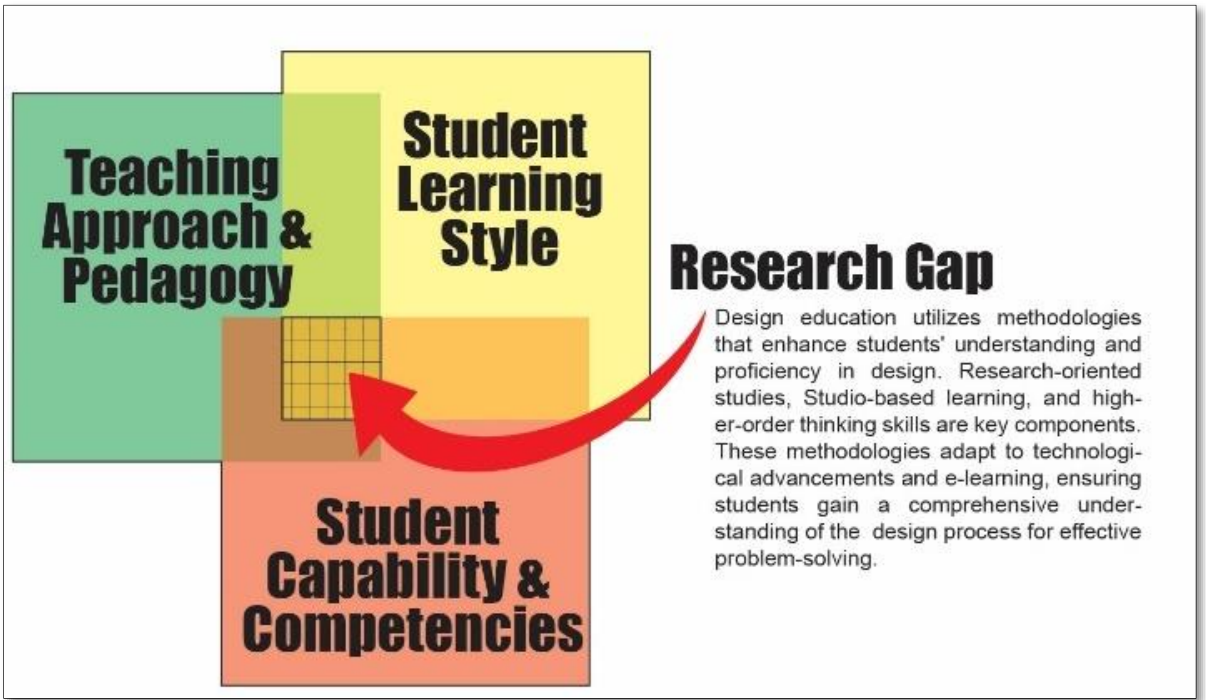


Figure 4: The Research Gap Mapping

The challenge lies in industrial design education's ability to impart effective techniques to students for recognising and resolving product ideation issues in an ever-evolving world. To reach this goal, we must closely examine how industrial design is taught and done in the studio. Using problem-based learning to solve design problems comes with its problems. Finding and developing good ideas for actual products is essential for creating new products. Emphasising technology direction can inspire new product ideas, even in a volatile market.

Education providers should take the initiative to thoroughly analyse approaches for incorporating design thinking competencies into their course outlines. Several prominent academic institutions endeavour to provide the public with access to their educational resources. The educational structure in Singapore and Malaysia places significant emphasis on preparing students with design abilities that are important for effectively addressing and resolving a wide range of difficulties. However, it is imperative for designers to effectively respond to the requirements of the creative industries by producing design outputs that have the potential to develop into successful brands. As stated by Lim (2015).

The pedagogical approach employed in design education is often regarded as a crucial component, as it facilitates students' acquisition of knowledge and understanding in design. Numerous scholarly investigations have demonstrated the potential of research-oriented design studies in enhancing students' proficiency in utilising studio-based learning methodologies. In Malaysia, Design Studio Learning incorporates higher-order thinking skills, 21st-century learning, CGPA, and 6P to enhance the educational environment (Zahari et al.). Nevertheless, these circumstances can be modified to correspond with shifts in the academic and instructional landscape, which may entail technological advancements and the implementation of e-learning methodologies. It is imperative for students studying industrial design to get a comprehensive understanding of the design process to identify and address the underlying challenges within their work effectively.

Spatial Ability in Design Thinking

Design students learn best when their curriculum follows a clear progression from basic skills to more complex, real-world applications. Researchers Wrigley, Mosely, and Tomitsch (2018) studied the academic success of design undergraduates in the UK. They found that the content students receive sometimes only partially helps them improve their understanding and knowledge application. A new metric has been developed to measure problem-solving skills in design thinking. Design thinking is often suggested as a method that can help address complex modern issues. Chesson (2017) believes unlocking dormant talents can increase design thinking proficiency.

Sutton and Williams examined the impact of spatial abilities on design thinking cognition. They studied first-year design students' Spatial Ability evaluation findings, considering gender, university admission score, and graphics course performance. Total spatial performance was slightly correlated with university entrance test marks, but outcomes at each level were diverse. Sutton and Williams (2010) found a negative correlation between high UAI scores and 3DAT exam performance, indicating that students with high UAI scores may lack spatial abilities and vice versa.

Significance and Knowledge Contribution

The study highlights the importance of spatial abilities in industrial design and design thinking. It highlights the potential impact of these abilities on various fields, including architecture, engineering, and STEM. Enhanced spatial reasoning can improve design, innovation, and analytical performance. Students with strong spatial abilities in industrial design can generate creative design solutions and tackle intricate challenges. This advancement encourages the cultivation of critical thinking and creativity, essential for thriving in the ever-changing realm of industrial design. The research emphasises that students with strong spatial abilities have a greater capacity to comprehend and address design tasks, resulting in enhanced academic and professional achievements. The study is driven by the increasing demand for spatial design thinking in industrial design education, aiming to equip students with the necessary skills to tackle intricate problems and foster innovation.

Conceptual Framework

Spatial design thinking and industrial design education scholarship will be thoroughly examined. Its practice will help the researcher understand the topic better and identify critical areas that need extra study. The initial phase in research is instrument development. After understanding the subject, a tool is required to assess industrial design students' spatial design thinking competencies and capacities. Surveys, interviews, and portfolio evaluations are research tools.

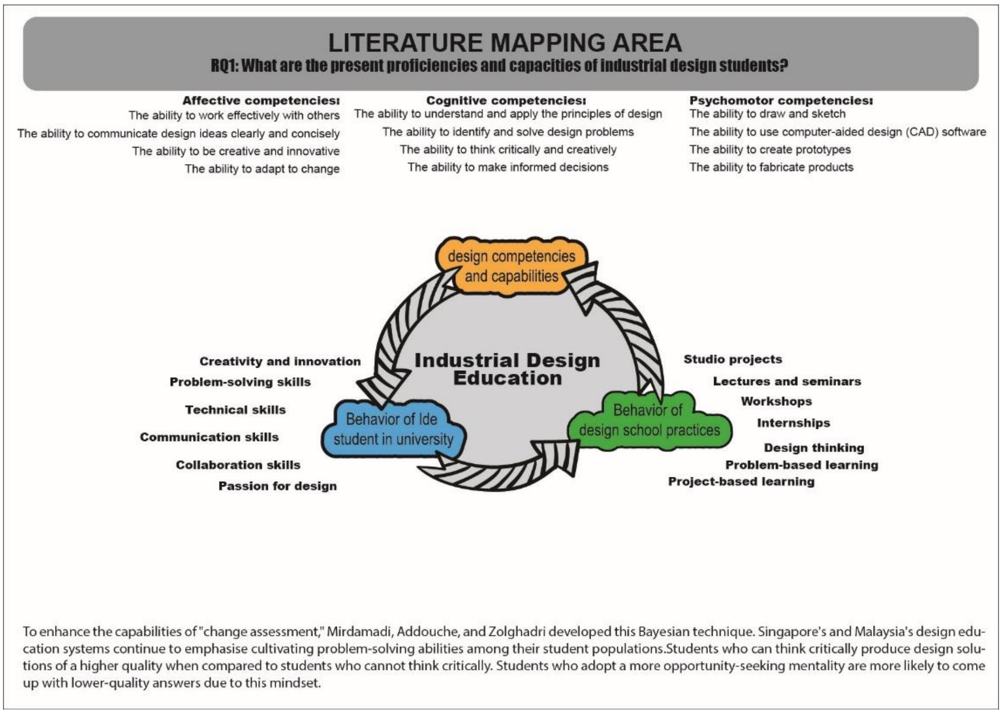


Figure 5: Literature Mapping Area

As shown in Figure 5, after constructing the study instrument, a representative sample of Malaysian higher education industrial design students must be surveyed. Student surveys, interviews, and portfolio analysis could be used to collect data for this project. Data analysis is essential to study. After data collection, industrial design students' spatial design thinking competencies and capacities must be assessed. Data analysis methods depend on the data, with quantitative or qualitative methods being viable. After evaluating Malaysian higher education industrial design students' spatial design thinking competencies and capacities, conclusions can be reached. The study's findings help industrial design educators improve spatial design thinking pedagogy.

Hypothesis

A significant positive correlation exists between students' spatial ability and their spatial design thinking competencies and capabilities. The research develops a hypothesis suggesting a notable positive link between students' spatial ability and their skills and capacities in spatial design thinking. It implies that those with more spatial ability are more inclined to possess enhanced spatial design thinking abilities.

Methodology

Data Collection Method

In August 2021, a survey was conducted among undergraduate students currently enrolled in various universities. The research focused on participants studying industrial design programs in several educational institutions in Malaysia. The data was collected online, with 102 students responding. However, it is essential to note that 10 participants were not eligible due to their previous involvement in the pilot study. As a result, 92 responses were included in the study.

The data shown above illustrates the educational background of the respondents about their secondary schooling. The data indicates that 34 respondents, accounting for 33.3% of the sample, pursued the Art Stream during their STPM education before enrolling in higher institutions. Subsequently, 22.5% or 23 participants followed a Diploma programme before starting their undergraduate studies. In contrast, 6.9% of the participants belonged to the Science Stream at the Sijil Pelajaran Malaysia (SPM) examination. A smaller proportion of 4.9% represented the Sijil Tinggi Persekolahan Malaysia (STPM) level. The statistics elucidated that students mainly from the art stream were the ones who predominantly chose industrial design courses.

The survey data comprises 102 participants from various universities that offer Industrial Design programmes. The highest number of respondents involved in this survey is from UTHM (28.4% or 29 respondents). Meanwhile, respondents from UiTM, UPM, and Politeknik Ibrahim Sultan were 24, 14 and 13, and USM and Unisza contributed one response from the survey.
The survey shows that Industrial Design is the most popular field of study among students, with 49 students pursuing this major. The remaining students are categorised into Furniture, Product, Automotive, Management and Administration, and Public Administration. A few students pursue various academic disciplines, such as Furniture and Industrial Design. The cumulative percentage column shows that 39.2% of the student population is pursuing a Product, Furniture, or Industrial Design major. The survey includes 102 students.

Demographic Study							
Description	Frequency	Percent	Valid Percent	Description	Frequency	Percent	Valid Percent
Age				Current semester study			
Below 20	23	22.5	22.8	Semester 01	1	1.0	1.0
21-23	66	64.7	65.3	Semester 02	21	20.6	20.6
24-26	11	10.8	10.9	Semester 03	5	4.9	4.9
27-29	1	1.0	1.0	Semester 04	46	45.1	45.1
Missing	1	1.0		Semester 05	8	7.8	7.8
Currently, Study?				Semester 06	10	9.8	9.8
Diploma	35	34.3	34.7	Semester 07	1	1.0	1.0
Degree	66	64.7	65.3	Semester 08	6	5.9	5.9
Missing	1	1.0		Graduated	4	3.9	3.9
Education Background Before Current Study?				Majoring			
Science Stream - SPM	7	6.9	6.9	Product	4	3.9	3.9
Art Stream - SPM	17	16.7	16.7	Furniture	36	35.3	35.3
Science Stream - STPM	5	4.9	4.9	Automotive	2	2.0	2.0
Art Stream - STPM	34	33.3	33.3	Industrial Design	49	48.0	48.0
Matriculation	9	8.8	8.8	Managementn admnstrtion	1	1.0	1.0
Foundation	3	2.9	2.9	Public administration	1	1.0	1.0
Diploma	23	22.5	22.5	Furniture, Industrial Design	3	2.9	2.9
Others	4	3.9	3.9	Product, Automotive, Industrial Design	3	2.9	2.9
Currently Attending University at				Product, Furniture, Industrial Design	3	2.9	2.9
UPM	14	13.7	13.7	Current semester study			
UTHM	29	28.4	28.4	Semester 01	1	1.0	1.0
UiTM	24	23.5	23.5	Semester 02	21	20.6	20.6
UIA	2	2.0	2.0	Semester 03	5	4.9	4.9
USM	1	1.0	1.0	Semester 04	46	45.1	45.1
UMK	9	8.8	8.8	Semester 05	8	7.8	7.8
UCTS	5	4.9	4.9	Semester 06	10	9.8	9.8
UNIKL	4	3.9	3.9	Semester 07	1	1.0	1.0
UNISZA	1	1.0	1.0	Semester 08	6	5.9	5.9
POLITEKNIK	13	12.7	12.7	Graduated	4	3.9	3.9
Majoring							
Product	4	3.9	3.9				
Furniture	36	35.3	35.3				
Automotive	2	2.0	2.0				
Industrial Design	49	48.0	48.0				
Managementn admnstrtion	1	1.0	1.0				
Public administration	1	1.0	1.0				
Furniture, Industrial Design	3	2.9	2.9				
Product, Automotive, Industrial Design	3	2.9	2.9				
Product, Furniture, Industrial Design	3	2.9	2.9				

Figure 6: Data on Demography Study

Analysis Framework
Before conducting the statistical analysis of the collected data, the researchers needed to assess the normality of the data distribution. The primary aim of doing a data normality test is to ascertain the most suitable statistical analysis method.

Data Normality Test
Two distinct methodologies exist for assessing the normality of test data: (1) employing a statistical test and (2) doing a visual assessment. Regarding the statistical test, the Kolmogorov-Smirnov and Shapiro-Wilk tests are well-recognised methods for assessing normality. Nevertheless, the Shapiro-Wilk test is deemed appropriate solely for cases when the sample size does not exceed 2000. In terms of visual examination, one may employ many techniques such as frequency distribution analysis, assessment of skewness and kurtosis, and review of Normal Q-Q plots. In this research study, the researcher chose to employ a combination of methodologies according to the findings in the existing literature. It has been noted that depending exclusively on the visual examination of diagrams can potentially result in an erroneous interpretation of the outcomes (Mazlan, 2012).

Table 1
Normality Test

Research Question	Variable	Skewness	Kurtois
1 & 2	DpI	-0.278	1.49
1 & 2	DPd	-0.528	1.421
1 & 2	Dpe	-0.421	0.947
1, 2, 3, & 4	Dpla	-0.356	0.196
1, 2, 3, & 4	DPlm	-0.428	1.15
1, 2, 3, & 4	Spatial Ability	-1.969	6.782

Skewness is a quantitative indicator of the degree of asymmetry exhibited by a given data distribution. A positive skewness denotes a rightward skew in the data distribution, whereas a negative skewness signifies a leftward skew. Kurtosis is a statistical term that quantifies the degree of peakedness in a given data distribution. A high kurtosis value suggests that the data distribution exhibits greater peakedness than a normal distribution. In contrast, a low kurtosis value indicates that the data distribution is less peaked than a normal distribution.

Table 2
Null Hypothesis Table

Variable	W	P-Value
Dpi	0.93	0
DPd	0.926	0
DPe	0.931	0
DPla	0.942	0
DPlm	0.932	0
Spatial Ability	0.841	0

None of the p-values support rejecting the null hypothesis of normality for any of the variables. It means that the data for all variables does not follow a normal distribution. The Shapiro-Wilk test is used to evaluate a dataset's normality assumption. It was named after its creators, Samuel Shapiro and Martin Wilk. The test compares the null hypothesis that the data follows a normal distribution to the alternative. It can identify departures from normality in small to intermediate sample sizes. The test statistic is calculated using the Shapiro-Wilk test. The Shapiro-Wilk test is used to determine if a dataset is usually distributed. The test results in a statistic (W), which tells us how well the data fits a normal distribution. When W is high, the data is more likely to follow a normal distribution, while a low W value suggests otherwise. The p-value represents the likelihood of getting the observed data if the null hypothesis of normality were true. If the p-value is less than 0.05, we can reject the null hypothesis and conclude that the data is not normally distributed. In our example, the p-value for all variables is 0.000, below the 0.05 statistical significance level. The result leads us to reject the null hypothesis and conclude that all variable data does not follow a normal distribution. Furthermore, all variable data has a slightly skewed proper distribution and higher kurtosis than a normal distribution. It indicates that the data is non-normally distributed.

Table 3
Normality Test

Tests of Normality							
		Skewness		Kurtosis		Shapiro-Wilk	
	Historgram	Statistic	Std Error	Statistic	Std Error	Statistic	Sig.
H1	Not Symmetrical	-1.723	0.239	7.973	0.474	0.884	0.000
H2	Not Symmetrical	-1.492	0.239	6.073	0.474	0.895	0.000
H3	Not Symmetrical	-1.411	0.239	5.934	0.474	0.909	0.000
H4	Not Symmetrical	-1.223	0.239	4.300	0.474	0.907	0.000

The Shapiro-Wilk test checks if a data set is usually distributed. This test assumes that the data is normally distributed, and if it yields a p-value of less than 0.05, the null hypothesis of normality can be rejected. In this case, the Shapiro-Wilk test was applied to four variables, H1, H2, H3, and H4, resulting in a p-value of 0.000 for each variable. Therefore, we can reject the null hypothesis of normality for all four variables. Skewness and kurtosis are two statistical measures used to assess the symmetry and peakedness of distribution, respectively. For a normal distribution, the skewness is zero, indicating the distribution is symmetric, while the kurtosis is three, implying that the distribution has a moderate level of peakedness. In this case, the observed skewness and kurtosis values for the four variables deviate from the expected values under the assumption of normalcy.

The outcomes of the normality tests indicate that the data about all four variables does not exhibit a normal distribution. Therefore, it is not advisable to employ parametric statistical tests, such as the t-test and ANOVA, to analyse the data. Non-parametric statistical tests, such as the Mann-Whitney U and Kruskal-Wallis tests, are recommended instead of other methods.

Findings

Hypothesis Testing

The data normality test revealed that the data does not follow a normal distribution, prompting Spearman's Rank Correlation, a non-parametric statistical method for examining hypotheses. The correlation coefficients were computed using SPSS v25.

Table 4
Spearman's Correlation on Elements

Spearman's rho Correlations						
		DPi	DPd	DPe	DPla	DPlm
SpatialAbiity	Correlation Coefficient	0.019	0.132	0.133	0.010	-0.003
	Sig. (2-tailed)	0.849	0.187	0.182	0.918	0.978
	N	102	102	102	102	102

**. Correlation is significant at the 0.01 level (2-tailed).

The table above displays the results of a statistical test that evaluates how two variables are related. Specifically, it shows how Spatial Ability is related to five other factors. A strong relationship between two variables means they increase or decrease together, but only sometimes at the same pace. In this case, all the correlations are positive but weak. The highest correlation is between Spatial Ability and Dpla, followed by the correlation between Spatial Ability and Dpe. All the correlations are statistically significant, with p-values under 0.01. However, these p-values assume the data follows a normal distribution, which is not the case here. Therefore, the p-values may only be partially accurate.

Spearman's rank correlation test shows a slight positive relationship between spatial ability and the five variables. However, since the data is not normally distributed, it is essential to interpret the results carefully. Here are some other scholarly interpretations of the findings. The weak correlation between spatial ability and the different variables means no strong relationship exists between them. Since the data is not standard, we cannot use regular statistical techniques to analyse it. Finally, more research is needed to confirm the results of this study and understand the connections between spatial ability and other characteristics.

Table 5
Spearman Correlation on Hypothesis

Spearman's rho Correlations					
		H1	H2	H3	H4
SpatialAbiity	Correlation Coefficient	.454**	.567**	.545**	.237*
	Sig. (2-tailed)	0.000	0.000	0.000	0.016
	N	102	102	102	102
**. Correlation is significant at the 0.01 level (2-tailed).					
*. Correlation is significant at the 0.05 level (2-tailed).					

The table provided shows the results of a correlational study on the relationship between five variables: H1, H2, H3, H4, and spatial ability. The Spearman's rho correlation coefficient was used to measure the strength and direction of the correlation between each pair of variables. A correlation of 0.000 is considered a non-significant correlation. In contrast, a correlation of 0.010 is regarded as a weak correlation, a correlation of 0.050 is considered moderate, and a correlation of 0.090 is regarded as a strong correlation.

There is a strong positive correlation between H1 and SpatialAbility ($r_s = 0.454$, $p < 0.01$). It suggests that the better learners describe a concept, the more likely they are to have a high spatial ability. There is a strong positive correlation between H2 and spatial ability ($r_s = 0.567$, $p < 0.01$). It suggests that the better learners are at identifying the fundamental concepts of a topic, the more likely they are to have a high spatial ability. A strong positive correlation exists between H3 and SpatialAbility ($r_s = 0.545$, $p < 0.01$). It suggests that the better learners are at designing learning activities, the more likely they are to have a high spatial ability. A moderate positive correlation exists between H4 and spatial ability ($r_s = 0.237$, $p < 0.05$). It suggests that the more learners are engaged in the learning process, the more likely they are to have a high spatial ability. There is a strong positive correlation between SpatialAbility and SpatialAbility (rs = 1.000, $p < 0.01$). It is unsurprising, as spatial ability measures one's thinking ability in three dimensions.

Overall, the results of this study suggest that there is a strong positive correlation between spatial ability and all four of the learning elements. It indicates that spatial ability is an essential factor in learning. It is important to note that correlation does not equal causation. Just because there is a correlation between two variables does not mean that one causes the other. In this case, the correlation between spatial ability and the learning elements may be due to different factors, such as the learner's intelligence or prior knowledge. However, the results of this study do suggest that spatial ability is an essential factor in learning. By focusing on developing spatial ability, learners can improve their chances of success in school and other areas of life.

Hypothesis #1

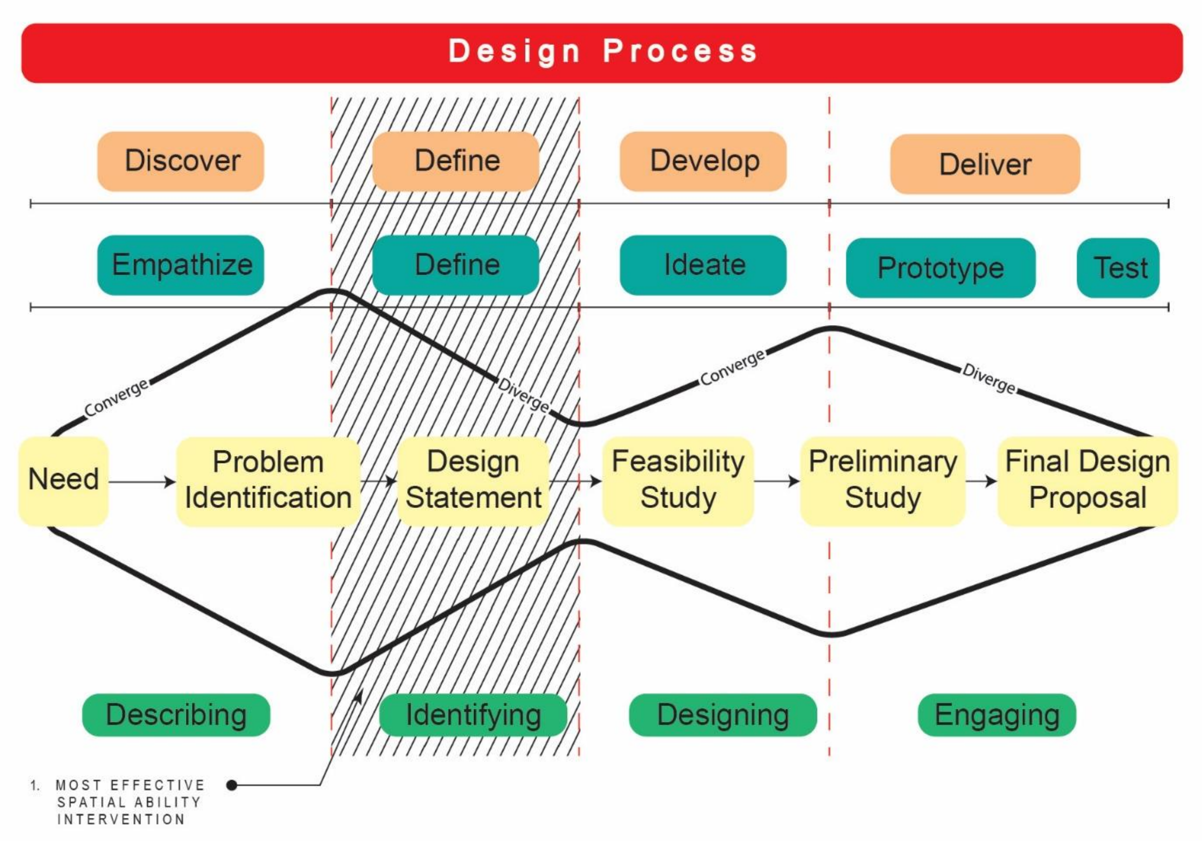
H1: To describe and identify the level of competencies and capabilities among industrial design students in higher education universities in Malaysia. There is a significant and positive association (rs = 0.454) between the act of describing and the process of learning. The proposition posits that learners who effectively articulate an idea tend to retain it in memory.
Table 6: H1 Correlation Value with Spatial Ability

Element	Hypothesis	r^s	Correlation	P-Value	Result	Containt
Describing	H1	0.454	Strong	($p<0.05$)	H1 substantiated	SA, Dpi
Identifying	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Designing	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Engaging	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

The table shows the findings of a correlational investigation examining the association between four variables and the learning process. The aspects encompass the description, identification, design, and engagement processes. All the hypotheses (H1, H2, H3, and H4) were confirmed, indicating the presence of a statistically significant association between each variable and the learning process. A correlation coefficient of 0.454 is deemed necessary, while a correlation coefficient 0.567 is regarded as robust. A correlation coefficient of 0.237 is commonly considered to indicate a moderate level of correlation.

Describe and learn have a significant positive correlation (rs = 0.454). The idea is that people who can explain something well remember it. Identification and learning are positively correlated (rs = 0.567). The notion states that students who identify a subject's fundamental principles are likelier to learn it. Designing and learning are positively correlated (rs = 0.545). The idea is that those who can create learning activities know more. There is a moderate positive association between participation and learning (0.237). The notion states that student engagement improves learning results.

Table 7
Integration of Multiple Design Process



Conclusions

The study emphasises the significance of mastery in four aspects of design thinking: articulating, identifying, creating, and linking, for the best possible educational results. It highlights that these dimensions do not have a direct cause-and-effect connection but concentrate on these fundamental characteristics in academic settings. The research examines the application of spatial design thinking among industrial design students in Malaysian higher education institutions. The findings indicate that a progressive improvement in spatial abilities positively impacts students' comprehension of design assignments and their capacity to identify and surmount design challenges. The study proposes that integrating design thinking into the curriculum, encompassing human-centred spatial design thinking, creativity, and critical thinking, is essential in design education. This programme will provide students with the necessary skills to excel in the digital economy, empowering them to address intricate problems and generate ground-breaking solutions. The results can be utilised to build strategies to improve design education in Malaysia and other nations.

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