Studying the Development of Design Thinking of Undergraduate Engineering
Students in Singapore: Qualitative Reflection Analysis (Research)

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Abstract

This study contributes new knowledge to engineering education research by exploring the development of Singaporean students' decision-making and justification over time when partaking in a 13-week undergraduate engineering course on industrial design with the explicit task of self-reflection at set points during the course completion. With the rising relevance of authentic learning in the classrooms, it is becoming more pertinent to teach engineering students the skill of problem scoping (i.e., determining the nature and boundaries of a problem) to succeed in future work in both industrial and academic environments. Based on Stanford University's Empathize, Define, Ideate, Prototype, Test (EDIPT) design thinking model, the effectiveness of asking students guided questions to reflect on their approach to problem scoping is analyzed while tackling complex engineering problems provided by industry partners. The overarching research question is: to what extent is the EDIPT framework relevant in Singapore? A qualitative approach and deductive analyses were employed to elicit and explain the findings, which were then mapped to the aspects of the EDIPT. Ten participants were randomly selected from a cohort of third-year undergraduate students enrolled in an engineering course from a research-focused university in the Southeast Asia region. During this period, students are organized by university faculty and their industrial mentors into design teams of six or seven to ideate, prototype, and evaluate solutions to real-life industrial problems. The students' key ideas and corresponding direct statements were collected from five self-reflections. These reflections focused on their individual and team responses and were mapped to the five EDIPT aspects. Findings showed that the student usage of the EDIPT thinking framework increased over the weeks and that the EDIPT was a robust lens to evaluate the effectiveness of the selected reflection questions. Through these analyses, key EDIPT ideas related to problem scoping skills of engineering students within the Singaporean context were identified, showcasing the relevance of the EDIPT model in Asia. Educational and theoretical implications were discussed.

Introduction

The worldwide trend towards technology-driven development is becoming increasingly evident, creating new demands and challenges for education, including engineering education. The current workforce requires interdisciplinary knowledge and professional skills (Tan, 2021). Hence, the everyday teaching and learning methods may need to be revised to ensure that students are sufficiently equipped with the skills required in the workforce (Venkatesh et al., 2022). Instead, learners need to accept a new type of learning where knowledge is gained and must be able to apply any information and concepts learned from different viewpoints (Tan, 2021). To meet the drastic changes in the world, many countries have released educational policies to promote innovation. Western countries, such as U.S. and Australia, have paid much attention to curriculum reform that allocates a massive amount of money to promote STEM curriculum and teachers' training [1, 2]. In the Asian context, China launched a Strategy of Invigorating the Country through Science and Education known as Kejiao Xingguo, which identified science and technology as the essential subjects to develop nations' 21st-century skills [3]. Since 1997, the Ministry of Education of Singapore has implemented 4 ICT-in-Education Masterplans, which guided the development of technology-enriched school environments for teaching and learning [4].

Even with abundant financial support and teacher training from the government, STEM education still needs to improve. Industry and academics have expressed concerns about engineering graduates' ability to work in the industry because of impractical engineering curricula devoted to basic science [5]. It has become a challenge for educators to integrate theoretical and practical knowledge when designing programs. To fix this problem, researchers focused on improving their teaching methods and enriching students' practical experience in projects. Moreover, recognizing the cultural background and prior knowledge that engineering students bring to the classroom is essential to the design thinking process [6]. Rather than assuming all students have equal learning opportunities, such critical subjects in STEM, especially engineering, should adopt the funds of knowledge approach to promote fairness and inclusivity for students from diverse backgrounds [7]. Some studies have already proved that design thinking is a beneficial way to enrich students' practical experience and help them to find better job opportunities. Stanford University's Empathize, Define, Ideate, Prototype, Test (EDIPT) design thinking model is broadly integrated with education worldwide [8]. However, whether this model is suitable in Singapore is still being determined. Therefore, a qualitative approach was conducted to explore its effectiveness in the Singaporean context and to give relevant suggestions to support engineering students learning.

Literature review

The Importance and Application of Design Thinking

Design thinking (DT), or human-centered design, has grown in popularity over the previous two decades. The concept of DT was first used by Simon [9], the founder of artificial intelligence. Archer [10] believed that "design" has to be acknowledged as a foundational part of education, and in Rowe's work [11], DT has explicated the ways of knowing designers. Goldschmidt [12] mentioned that designers see DT as a learning process, and the business community views it as a process based on knowledge. While for managers, DT refers to developing and implementing strategies [13]. Even though these researchers identified DT differently for their own areas, it is regarded as a strategy for innovation based on decades of study on developing new products [14,15].

As the 20th century progressed, due to the support of new technologies, DT applied to various fields such as IT, business, and medicine. Oxman [16] used a thinking map in the teaching method. Earle and Leyva-de la Hiz [17] explored sustainability-focused education difficulties using DT and new technologies, such as emerging technologies and virtual reality (AVR). The current application of digital design thinking was proposed and started to draw researchers' attention [18].

In general, DT is described as a creative and analytical process that offers chances for experimentation, model creation and prototyping, feedback gathering, and redesign [19]. Seidel and Fixson [20] concluded three main activities of DT, including need-finding, brainstorming, and prototyping. Furthermore, during the design process, educators and learners must fully use skills in learning and innovation, critical thinking and issue resolving, communication and teamwork, etc. [21,22]. Hence, DT is also crucial for developing 21st-century skills [23].

Although Robbins [24] thought DT always puts the user first, this easily leads to losing innovation. Especially for designers, constant experimentation and testing in DT is a functional way to solve the wicked problems of daily life [17,25]. Several studies have shown that DT could achieve positive results in dealing with a large number of everyday-life challenges, such as urban environments [26], sustainable consumption and production [27], customer experience [28], and health care [29]. In engineering projects, engineers are required to have the competence to design practical solutions to meet the needs of society as well [30]. Therefore, for researchers and practitioners, it is crucial to have a thorough comprehension of the procedures and models used in employing design thinking or human-centered designs.

Design Thinking in Education

Some scholars have introduced the model of DT into the education field and placed it into practice, such as by integrating design thinking principles with educational models or instructional design [31]. As design thinking is naturally embedded within engineering problems, it is essential for students to start to be exposed as early as possible to acquire the necessary problem-solving skills. To initiate, teachers should be equipped to teach engineering in their teaching subjects [32]. Carroll et al. [33] combined DT with a classroom learning environment in various manners and found how DT linked to academic standards and the learning of content in the classroom. Meanwhile, DT is interdisciplinary [34], building new scholarly spaces by combining disciplines. McLaughlin et al.'s [35] work proved this view and portrays DT's validity across fields and institutions.

In engineering, design is seen as the main or distinguishing activity [9]. As such, it is necessary for engineering educators to combine the DT model with the course outline and cultivate students' design thinking, just as some scholars did in marketing education [36]. Furthermore, engineering education is distinct from other disciplinary education due to various student-related variables such as demographic data, prior achievement, and performance measures [37]. Therefore, adapting the DT model to suit engineering education is essential. DT is used to introduce entrepreneurship to science and engineering students, which is a great challenge and chance for developing students' tangential skills and knowledge about technology commercialization [38]. American scholars used a case study approach to integrate DT into the engineering education framework [39]. In this project-based learning, the student's competencies and skills were significantly enhanced, which was thought to benefit them in their future careers. Furthermore, a study about biomimicry, an interdisciplinary design thinking approach that answers engineering issues by taking inspiration from nature, explored the understanding and perceptions of biomimicry among undergraduate and high school students from different countries [40]. The findings revealed that students had limited knowledge of its applications in engineering and required more assistance in developing their ideas into prototypes using a top-down approach, also referred to as problem-driven method or indirect biomimicry that involves using biological systems as a model to design new prototypes, which reflects the pertinence of DT in education. Nonetheless, in the Asian context, there is little research concerning applying DT in engineering education.

The EDIPT model

Some popular DT models are Simon's three-stage linear, IDEO, and EDIPT models. Initially, DT courses in engineering and design were based on Simon's three-stage linear model, including analysis, synthesis, and evaluation [9]. IDEO expanded the DT model through an iterative Discover, Interpretation, Ideation, Experimentation, and Evaluation cycle to innovate design work [41]. Stanford University's Educational Design Lab further integrated DT into curriculum and teaching practices by proposing the EDIPT model, currently the most widely adopted in education worldwide [8]. The EDIPT model is implemented in five stages - Empathy, Define, Ideate, Prototype, and Test - with a Transition phase between the two stages. It is worth noting that the EDIPT model emphasizes iteration rather than a mono-linear model. In other words, learners can always jump back to a previous stage to work or think again when they encounter difficulties at one stage. As such, the process requires the learner to be deeply involved in the project and to collaborate and interact effectively to produce the final work, product, or solution.

In the current context, some researchers have applied the EDIPT model to the field of education. For instance, design thinking with aspects of EDIPT is a core module for all first-year science students and an introductory course for a minor in Innovation and Entrepreneurship at Shanghai Tech University [42]. The aim of this course is to allow students to utilize scientific methods and critical thinking skills to collaborate with teammates of different disciplines and solve real-world issues [42]. In higher education, researchers have focused more on enhancing learners' competencies.

Additionally, children from six institutions in Shaanxi Province have taken part in virtual workshops focused on design thinking and STEM education [43]. Plan International has also reached a broad audience in implementing design thinking in STEM. Doing so has aided in reducing gender stereotypes about STEM education and has made students more comfortable exploring STEM subjects from a younger age [43]. Yang and Qi [44] also applied the EDIPT model to English video learning resources for business. However, research studies still need to be included in Singapore, where the EDIPT model and education are integrated, particularly in engineering education. To explore this research gap, we designed a study focusing on the following question: To what extent is the EDIPT framework relevant in Singapore?

Methodology

Research Design

This study was based on a 13-week undergraduate engineering course in industrial design that includes the explicit duty of self-reflection several times throughout the course. A qualitative research design explored the relevance to undergraduate engineering education students and the EDIPT framework.

Participants

One hundred four third-year engineering students were registered in the 13-week undergraduate engineering course. Ten participants of the 104 students were selected arbitrarily for our investigation. Each learner was given a personal code depending on their name, index, participation group, and admission year (i.e., Fall 2022 [F22]). All the involved students were enrolled in the same major. All potential participants were first contacted by the university faculty and informed about this study, and each student gave their written informed consent. Table 1 shows the demographic information of the ten selected participants.

Table 1. Demographics of the selected 10 participants

Number	Group	Gender	Ethnicity	Nationality
026	G10	M	Chinese	Singapore
054	G08	F	Chinese	Singapore
060	G07	F	Malay	Singapore
074	G11	M	Chinese	Singapore
076	G14	F	Chinese	China
078	G12	M	Chinese	Singapore
085	G06	M	Chinese	Singapore
088	G17	M	Chinese	Singapore
089	G05	M	Chinese	Singapore
096	G16	F	Chinese	Singapore

Data Collection

Participants were divided into six or seven design teams and guided by academics and industry mentors to brainstorm, prototype, and assess solutions to industrial challenges. At a certain point in the course, participants were requested to write down their reflections based on specific questions, such as "What is your approach to identifying the problem statement and problem?", "How did design thinking and negotiations with your group influence your approach to the process?" Each of the reflective questions was answered with over 200 words. Five self-reflections by the students were used to compile their main points and the related direct statements. These reflections were mapped to the five EDIPT stages and centered on their individual and team reactions, which recorded the students' problem-solving and decision-making skills development throughout the course. Ethical approval was obtained from the first author's university.

Data Analysis

Content analysis was used to analyze the five reflections. Content analysis is a technique that has been extensively used in studies analyzing newspaper articles, interview transcripts, and textbooks. The deductive content analysis method was used to conduct the coding process drawing upon the EDIPT framework. Cue words or sentences in the reflections included in the analysis must show evidence of the design thinking framework, including how students use EDIPT to think and solve difficulties.

Two researchers participated in the coding process. Each coder was given specific instructions for the EDIPT framework and coding reflections (see Table 1). Each design thinking stage was defined in EDIPT model instruction, and the cue words within each category were detailed in each coder's coding process. To be more precise, we used abbreviations for the names of each stage. "E" means Empathize. "E2D" means Empathize to Define. "D" means Define. "E2D" means Define to Ideate. "I" means Ideate. "I2P" means Ideate to Prototype. "P" means Prototype. "T" means Test. "P&T" means Prototype and Test. Furthermore, each researcher conducted a content analysis and independently coded the reflections according to their content. To ensure internal consistency, all inconsistencies and ambiguities were discussed by all researchers after completing the independent coding.

Table 2. EDIPT codes

Codes	Definition	Examples
E	The Empathize mode is the work students do to comprehend people in terms of students' design challenges.	*We scheduled a meet-up with the Bralco Advanced Materials representative and tried to understand their problems and situations that they needed help which led us to finding out that he was looking for specifically films as compared to thermal paste and this helped us narrow down what we were researching for. (Reflection1)*
E2D	This is a transition process from the Empathy stage to the Define stage. Students need to process everything they hear and see as they try to draw conclusions from empathic work. Information is unpacked to reveal what has been learned, and the relevant ideas are picked out in working toward the problem statement.	*Factors to consider would include where the interest of the industry's target audiences lie, by learning which, we can then tune the problem to be more specific towards meeting these interests and expectations. (Reflection2)*
D	The Define mode of the design process brings clarity and focus to the design space. When a problem statement addresses the user, need and insight is created.	*Defining the cause of these problems, followed by generating insights or clues as to the causes of these problems and their potential solutions, is also crucial in identifying the boundaries. (Reflection2)*
D2I	This is a transition process from the Define stage to the Ideate stage. Students need to identify a specific problem statement or brainstorming topic to propose a solution or idea.	*Our group was given quite a narrow problem, which is how to reduce energy consumption for ships. However, since many factors affect energy consumption, we attempted to narrow down our problem statement to tackle specific factors rather than leave it at a very general statement, "how to reduce fuel consumption." (Reflection2)*
I	Ideate is the mode of the design process where students focus on generating ideas with the prototype's goal in mind.	*Having a group discussion also probes our brains to think further into the problem as different types of ideas will be coming from every groupmate which will make me think more as I might not have thought of such ideas. (Reflection1)*
I2P	This is a transition process from the Ideate stage to the Prototype stage. During this transition, students will move multiple	*Once we had ideas, we compiled it [them] into a document and discussed on which idea would be a more viable and realistic approach in terms of the real-world setting. (Reflection2)*

	ideas into the prototype. Ideas are voted on and short-listed for the creation of the prototype.	
P	The Prototype mode is the repetitive creation of artifacts that aim to answer queries that get students closer to students' final solutions.	*As we had the opportunity to work with the materials that was [were] given in Professor [anonymized name]'s lab, we were able to make different samples that consisted of many different fillers. (Reflection4)*
T	The Test mode is when students garner feedback regarding the prototypes students have built from students' users and have another chance to gain empathy for the people students are designing for. The prototypes are tested and checked to see if they fit the needs well, and feedback is gained to understand what improvements can be made.	*Once that was considered, we printed the prototype out and have [had] our professor and the industrial supervisor to review [it] and give us feedback on area[s] for improvement. (Reflection3)*
P&T	More than a transition, prototype and testing occur in tandem. This is an iterative process where prototypes are constantly tested, and designs are tweaked until the best fit is gained.	*We then gathered feedback from the user about the product and asked probing questions about the product's logical flow, usability, and accuracy. (Reflection4)*

Findings

Our analysis reveals that the student usage of the EDIPT thinking framework increased over the weeks. As seen in Figure 1, the five stages were employed at specific and relevant project stages. For instance, reflections 1 and 2 included more empathizing and defining. From reflection three onwards, students move from empathizing and defining to prototyping and testing. The occurrence of stages appeared in a systematic and consecutive order. This suggests that the framework successfully guided the students' flow of thoughts when designing and problem-solving using the EDIPT model.

The transition stage from empathizing to defining had the highest frequency. A possible interpretation would be that this stage was the most challenging and essential. Students only need to understand the users' needs at the empathize stage. Often, students could ask others (teachers and peers) for help to assist their understanding at the empathize stage. However, from empathizing with defining the transition stage, students must process and internalize information independently. The transition stage requires a deeper understanding and stronger articulation of the concepts and ideas. Also, this was the first transition stage; essentially, students are still adjusting to the framework at this phase. Thus, this might explain why the stage had the highest frequency and usage.

Notably, the ideation frequency level was equally distributed throughout the five reflections. This suggests that students were engaged in ideation actively or at a similar level throughout the project. This means that from reflections 1 to 5, students were constantly ideating and brainstorming. The ideation process was a constant and ongoing process during the entire journey of the course. This favors the course as it aims to train students' inventive thinking and problem-solving skills. Overall, the frequency and occurrence of each stage are crucial in depicting how students cope with each EDIPT phase, including the transitions.

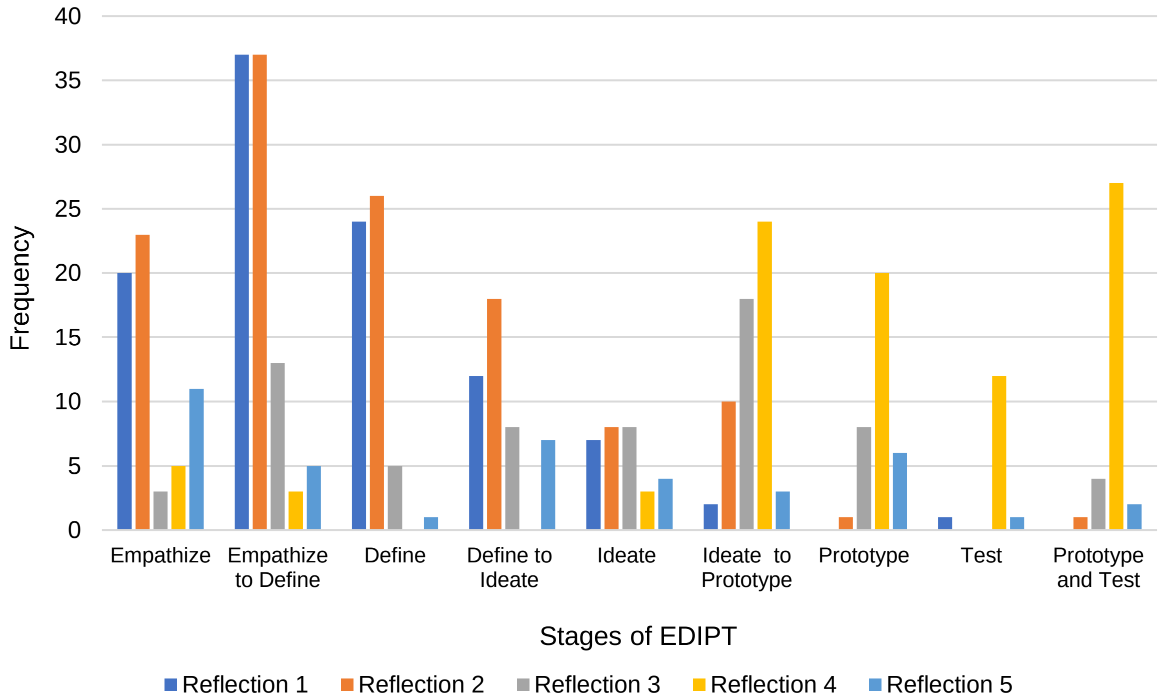

Fig. 1. Frequencies of Each Stage in Students' Reflections. (a) Students record their reflections as they work through the 13-week course assignments. (b) Frequency of different EDIPT framework stages in different reflections over time.

Further, our analysis shows that EDIPT was a robust lens to evaluate the effectiveness of the selected reflection questions. At the Empathy (E) stage, students used their empathy skills to find out users' needs and were more willing to ask for advice from professors and company leaders.

Next, for each stage of EDIPT, codes were entered into a word cloud generator. The high-frequency word list and word cloud were extracted for each stage. In the empathy stage (Figure 2), "research," "problem," "first," and "understand" appeared the most.

In the reflections, it was straightforward that students were willing to seek advice on things they did not understand, put in much effort to understand the given design challenge, target users, and comprehend what is required.

> *Being assigned the topic of developing thermal interface materials, I first had to understand what Thermal Interface Materials is even. (026_G10_F22, Reflection1)*

Fig. 2. Word cloud of Each Stage in Students’ Reflections - Empathy

In the transition process from Empathy to the Define stage (E2D), when students encountered difficulties during the project process, they liked returning to this stage and seeking the users' or other people’s advice. It was beneficial for them to rethink their project and change their position, so they could keep innovating and develop new ideas or solutions. At the same time, students generally went through the process of throwing out what they learned, unpacking, and using the relevant knowledge in crafting their problem statement.

> *After hearing my group’s thoughts on what we should be looking out for, I moved on to look, and it was when I found about Silver Nanowire Array-polymer composites which may help us. (026_G10_F22, Reflection1)*

At the Define (D) stage, students aimed to target a critical problem. In the word cloud for this stage (Figure 3), “problem” and “statement” had an overwhelming appearance among all words analyzed.

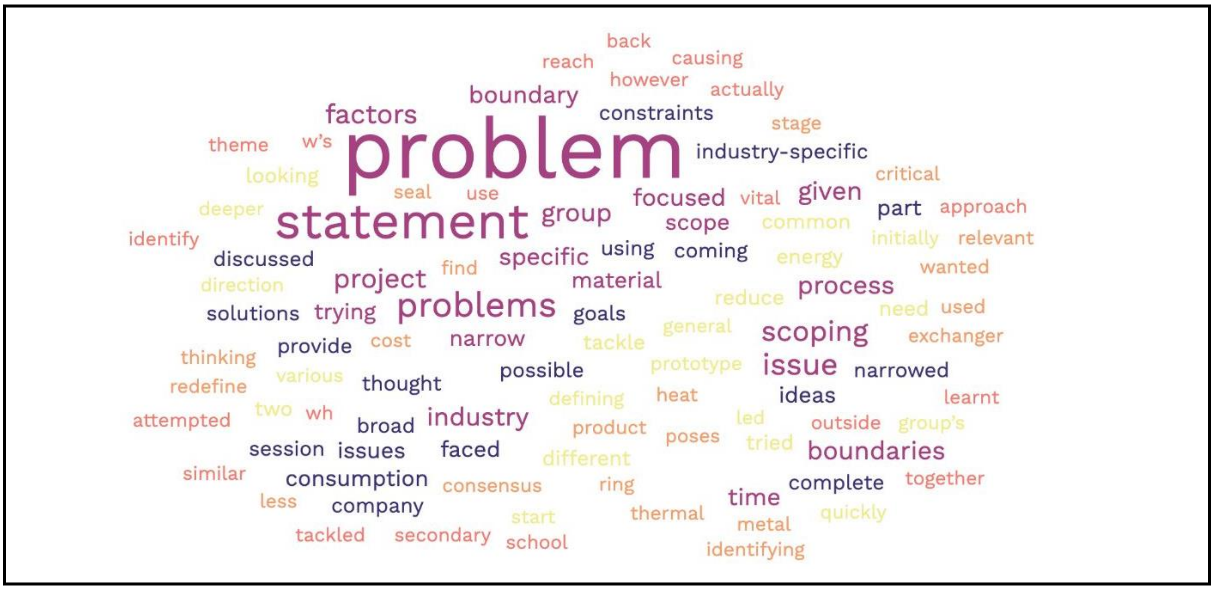

Fig. 3. Word cloud of Each Stage in Students’ Reflections – Define

Students appeared to have difficulty crafting an appropriate problem statement, especially when much background information was needed. This phase also seemed to be a long and tedious process. Most of these students prefer to use the "5W1H" rule to help them define their "pain points."

> *Also, as cliché or boring as it may sound, I actually made use of the 5W1H that we learnt in secondary school in my approach, where I focused on "what" and "why" as I feel that these 2 'W's are the most vital for both the problem scoping and coming up with the problem statement. (096_G16_F22, Reflection1)*

In transitioning from the Define to the Ideate stage (D2I), picking a straightforward, appropriate question guided students forward with projects. Students were quite apt in brainstorming ideas from the defined problem statement.

> *So we began questioning the logic of what our supervisors suggested and weaved their suggestions into how we could improve our process of ideation. (085_G06_F22, Reflection 3)*

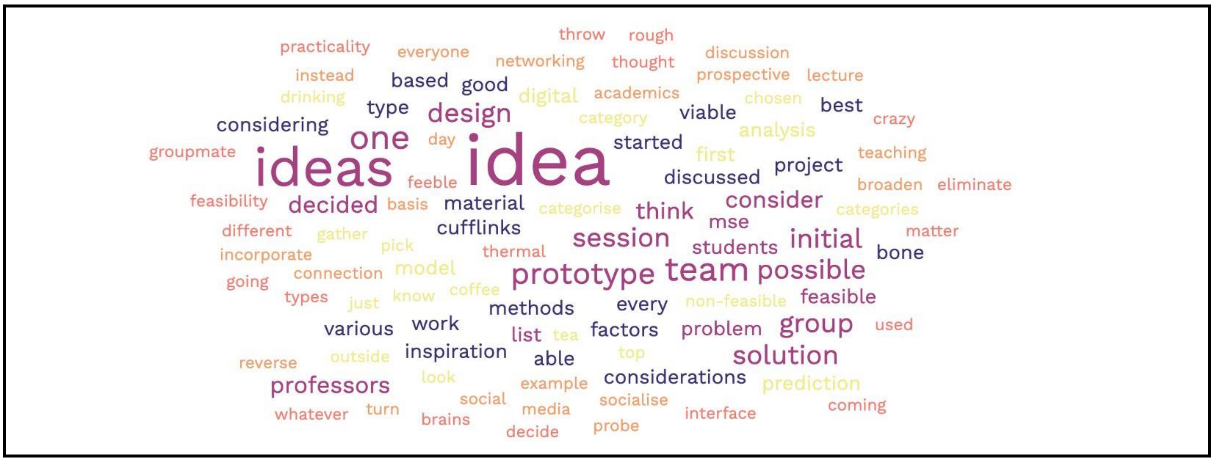

Fig. 4. Word cloud of Each Stage in Students' Reflections - Ideate

At the Ideate (I) stage (Figure 4), students did well in listening to other groupmates' ideas and tried to use several methods (e.g., making a list) to avoid missing ideas and hurting their groupmates' feelings. During brainstorming, students also developed teamwork skills as they learned to cooperate. They are generally able to come to an agreement and vote on the shortlisted ideas, leading to prototyping.

> *Whenever there is a debate among the team members, we will put down our ideas and to brainstorm each idea together, stating out the pros and cons of each idea. (078_G12_F22, Reflection 4)*

In transitioning from the Ideate to the Prototype stage (I2P), students moved from ideation to practice as their ideas were implemented in the real world. When students found that their ideas or plans were not working, they often returned to one of the previous stages to rethink and solve the problem. They generally agree and vote on the shortlisted ideas, ultimately leading to prototyping.

> *We started our brainstorming process by letting everyone in the group to familiarize with the methodology in which we will be using to build our*

prototype – using algorithmic engineering, basically, coding a 3D model instead of building one by the traditional CAD software. (054_G01_F22 , Reflection 3)

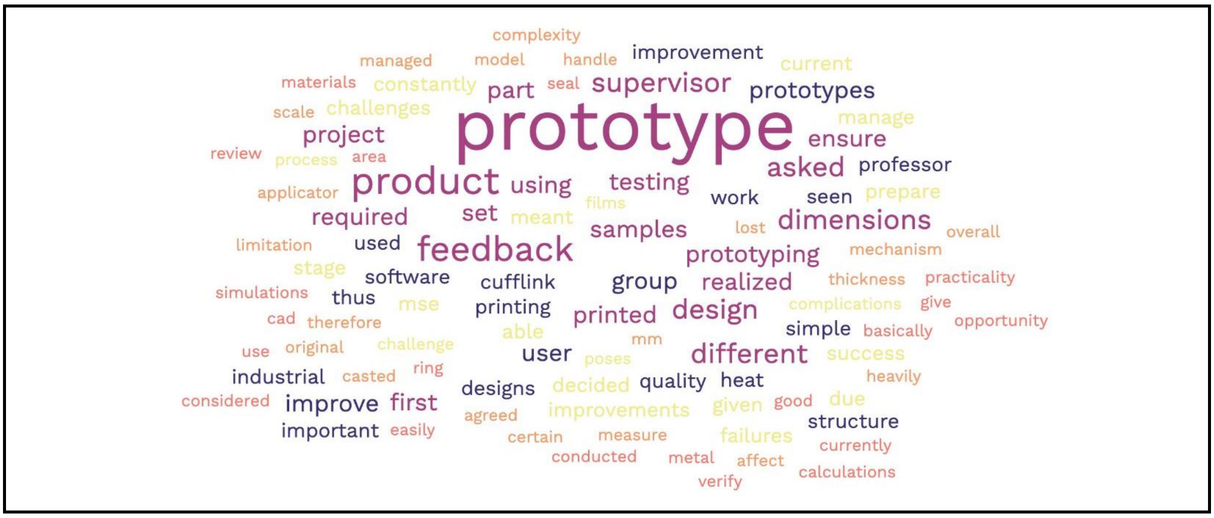

Fig. 5. Word Cloud of Each Stage in Students' Reflections – Prototype

At the Prototype stage, students generally found various possible materials to create their designs instead of being fixated on a particular one. This demonstrated their open-mindedness and willingness to ensure that the products were the best suited to the design challenge.

Our first prototype was to replace the entirety of the inner walls of a heat exchanger to gyroid lattices. However, after discussion with the mentors, we realized that this was not ideal due to challenges in pressure drops and difficulties in execution as they were too complex. (054_G01_F22, Reflection 4)

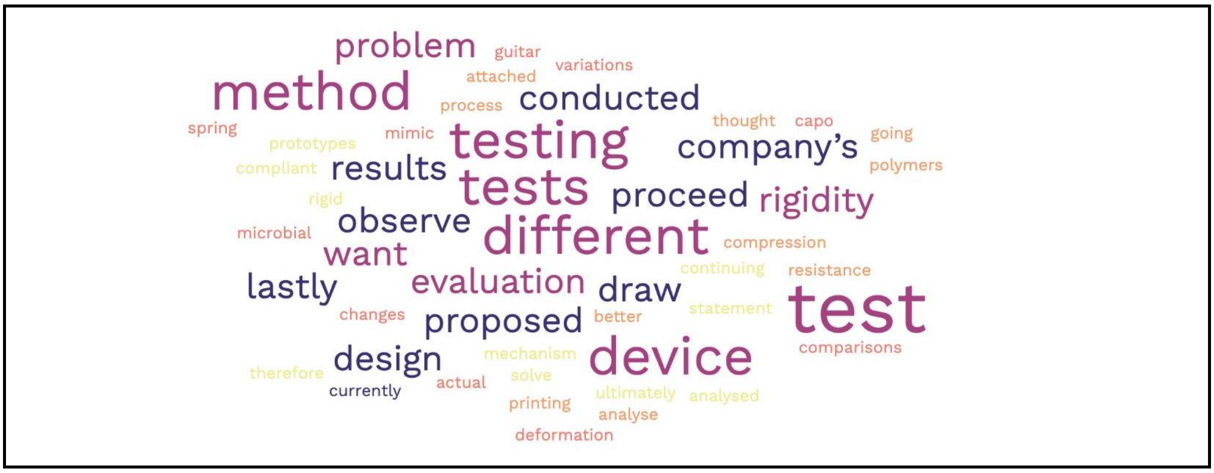

Fig. 6. Word cloud of Each Stage in Students' Reflections - Test

At the Test stage, students often created more than one prototype. They were open to seeking feedback on their prototypes and worked on their prototypes based on the ease of applicability and feedback gained.

Another test we conducted was a microbial/sterility test, where samples of our treated device were placed onto different nutrient plates to observe the devices' ability to remain sterile. (074_G11_F22 Reflection 4)

Regarding the transition from the Prototype to the Test stage (I2P), prototyping and testing are sometimes entirely intertwined. Students continue to adjust their prototypes through testing and re-engage in new rounds of testing to find the best possible fit that solves the issue.

> *For our project on the metal seal ring, our team had to redesign the 2D drawing of the CAD file given to us by our industrial supervisor as the drawing given was not completely joined together and we had to design it again. (096_G02_F22, Reflection 4)*

At the end of the analysis, the occurrences of codes tagged to each stage of EDIPT were counted and normalized against the total number of codes counted for a particular reflection (Figure 7). The percentages were further presented using a heat map (Figure 8).

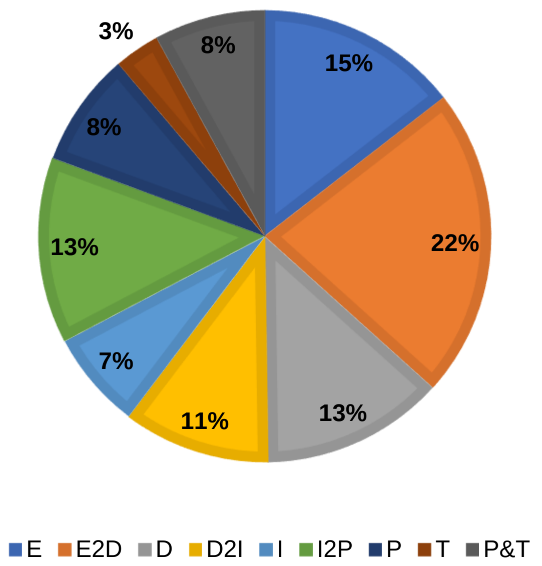

Fig. 7. The proportion of each EDIPT phase

Figure 8 shows that the first three stages of EDIPT accounted for nearly half of the total. In addition, the E to D stage accounted for the most significant proportion of all reflection content of students. Most of the codes in reflections 1 and 2 were in the *E* and *E2D* phases, while a gradual progression was observed from the *define* to *ideate* phases. As it progresses to reflection 3, the pattern of the heat map moves upwards, showing an increase in the *I2P* phase. By reflection 4, most percentage concentrates on the top of the map as students spent most of their time on the last two stages of EDIPT. The heat map from reflections 1 to 4 shows a diagonal progression from *empathy*, *define*, *ideate to prototype*, and *test*. Whereas for Reflection 5, it can be viewed outside the pattern as it was meant to ask the students' opinions and feedback about the overall EDIPT.

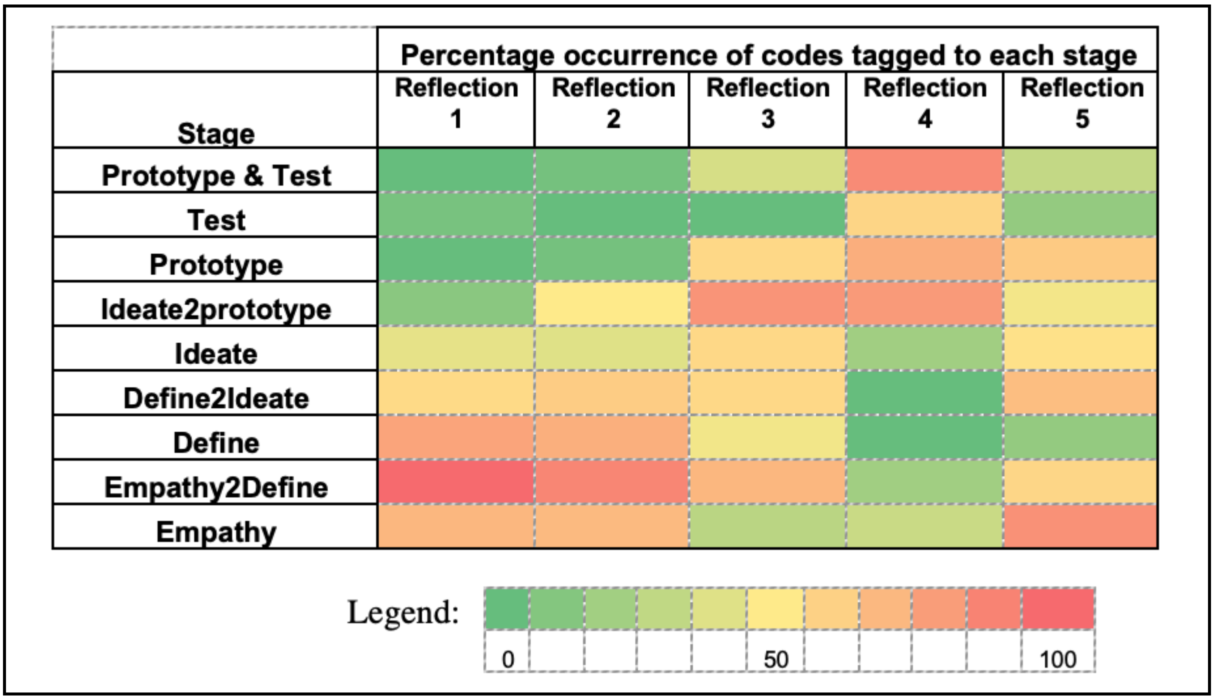

Fig. 8. Heat map based on individual reflections

Discussion

Through these analyses, key EDIPT ideas related to problem scoping skills of engineering students within the Singaporean context were identified, showcasing the relevance of the EDIPT model in Asia. First, the increased usage of the framework over the weeks shows that students tend to develop attachment and increase their tendency to think, rely and depend on the EDIPT framework as they engage in the project. As they gain familiarity with the framework, it acts as a safety net for them to explore, ideate, brainstorm, and test their ideas.

Essentially, the framework cushions their innovativeness, encouraging them to solve problems and tackle hardships systematically and continuously. The findings show that the model's five stages also maximized students' learning at each stage. This enables students to dive deeper into each stage of the problem-solving process. For instance, at the empathy stage, students do not stop at the phase where they ask why. However, it pushes them to understand the users' needs from primary and secondary sources, such as seeking advice from different stakeholders' perspectives. The high productivity resulting from using the model suggested that the model was relatively easy to understand, adapt to, and practice. Hence, the students were able to conduct a highly innovative design process with fruitful personal enrichment and team achievement.

The characteristics of professionalism displayed by the students also align with the research results in Venkatesh, Fong, and Yeter [44], where researchers investigate how engineering undergraduates consider ethics within their engineering courses. Similarly, Venkatesh et al. incorporated the EDIPT model to guide students through a newly designed engineering course [45]. Findings show that most students were fixated on professionalism and client-centered responsibility, such as meeting customers' requirements via problem-solving. Thus, it is evident that the EDIPT model is highly relevant in Asia as the concept and problem-solving mindset embedded in the model align with the existing skillset and critical thinking skills of the students in Singapore.

In the Western context, American scholars have utilized a case study approach to include DT in engineering education's framework [39], as opposed to the qualitative research design integrating problem-based learning and EDIPT used in this study. In terms of American study, students' competencies and skills were improved mainly, which were thought to benefit them in their future careers. This is similar to the results of this study conducted in Singapore, where it is demonstrated that the model is very relevant in Singapore's engineering education, where students' use of the EDIPT model was augmented over the weeks.

Furthermore, a study conducted in Ireland [49] utilized an eight-stage step-wise process in addition to a feedback loop in Virtual Curriculum Development Workshops, found that specific gaps which were related to the engineering program structure could be filled with the use of DT and that the present curriculum drove students to think in a 'Just-in-Case' manner – where students learned things in case they were going to be tested on them. With their DT approach, specific content about the learning outcomes could be made accessible to students. This study found that it is pertinent for students to learn the necessary soft skills from a young age to get multiple opportunities to apply them during their engineering course [49].

Moreover, there was great emphasis on the times and methods in which students' learners comprehend the relevance of the content they are taught [49]. This can be compared to the results of this study using EDIPT in an Asian context. As seen in the results, the framework managed to guide how students think and resolve issues with the model, suggesting that it aids them in understanding what they are being taught and how they are taught. Additionally, the fact that students had trouble identifying what corresponds to the different stages reflects the need for EDIPT to be employed at earlier stages and more frequently so that the framework can effectively guide them to do better.

Western studies integrate DT more passively, for instance, referencing the framework and utilizing it on a case-study basis or asking for feedback. In contrast, the Asian context seems more direct, for instance, making students work with each stage of the framework while completing their projects or reflections. Notably, the findings also highlight the usefulness and efficiency of the transition process in the model. Keywords and phrases such as "rethink," "re-engage," "unpack," and "vote and come to an agreement" often appear and occur during the transition phases. The transition phases are often the most challenging as they require students to challenge their ideas, each other's ideas, and previously proposed ideas. This stage challenges students' innovativeness, perseverance, resilience in facing hardships and failures, and communication skills with others. Values such as resilience, harmony, critical and inventive thinking, and communication are essential values the Singapore education system has emphasized from a young since pre-college education [46]. Thus, it also suggests why the students were able to adapt to the EDIPT model when they were first introduced to it during the 13-week course. Overall, the EDIPT model fits the education vision of Singapore and is relevant to the engineering and overall educational framework in Asia.

Implications, Conclusion, and Future Recommendations

To the best of our knowledge, the field of engineering education is still in its embryo stage to explore engineering practices and their implications in education in the Singapore context

[46,47-48], and very few studies focus on integrating the EDIPT model with education, especially in engineering education [45]. This paper conducted a qualitative approach and deductive analyses to explore this research gap to examine students using the EDIPT thinking framework during a 13-week undergraduate engineering course. Qualitative findings from students' learning experiences and reflections suggest that the model is highly relevant in Singapore's engineering education environment as students' usage of the model increased over the weeks. Through these analyses, key EDIPT ideas related to problem scoping skills of engineering students within the Singaporean context were identified, showcasing the relevance of the EDIPT model in Asia.

As the engineering industries proliferate, particularly in Asia, newer technologies, knowledge, and skills are now required. Institutions' teaching should be examined, updated, and refined to better prepare university graduates for the future economy. This study begins with understanding how engineering education can be improved and taught more practically by integrating the EDIPT model into students' learning and course curriculums. The analysis and interpretation of results rely on the theoretical framework of educational research of engineering and how EDIPT frameworks were integrated into educational practices. Future investigations will examine how applicable foreign research frameworks are in local practice contexts and how design thinking education strategies might be refined for engineering. In addition, the findings will inform future iterations of engineering courses on how to improve the teaching framework.

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