# Investigating Ethics in an Undergraduate Design Thinking Project:

# The Stanford EDIPT Framework Approach in Southeast Asia

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***Abstract*—This research is to practice a full paper that discusses ethics in engineering. Engineering graduates are expected to have ethical critical thinking and problem-solving skills to tackle real-world complex problems in the workplace. Course curriculum could benefit from more authentic learning and interdisciplinary teaching focused on engineering design and problem-solving. This pilot project incorporates a research-based design thinking framework EDIPT (Empathize, Define, Ideate, Prototype, Test), developed by Stanford University to guide students through conceptualization-to-production processes in a newly designed engineering course at an internationally-renowned university in Singapore. The study aims to equip students for ethical problem-solving, support more innovative and feasible ideas and products, and allow students to better exhibit knowledge and accomplish the Engineering Accreditation Board (EAB) requirements. 36 third-year engineering students (39% female and 61% male) participated in this study through hybrid online/offline course activities and working with industry partners for real-world problem-solving. While the entire project implements an exploratory sequential mixed method research design, with multi-layered research data including student interviews and in-course and post-course reflections, this paper focuses on the participants' open-ended pre-course survey responses about ethics in engineering. We conducted qualitative inductive analysis using an open coding technique and created descriptive codes. Preliminary findings suggest five emergent themes of ethical considerations, namely 1) client-centered responsibility, 2) intellectual property infringement/originality, 3) macro ethical considerations, 4) professionalism, and 5) others. Findings from this study will help to bolster research on ethical considerations in design thinking for the engineering field, as well as the applicability of foreign research frameworks in local practice contexts. Findings will also contribute to determining the best approach for improving the teaching framework for future iterations of the engineering courses, as well as assessing the suitability of applying design thinking to similar capstone courses within the university.**

***Keywords— Engineering design thinking, engineering education, undergraduate education, ethics, EDIPT***

## I. Introduction

Numerous studies [1; 2; 3; 4] suggest interdisciplinary STEM+C (science, technology, engineering, mathematics, + computing) education provides a massive amount of authentic learning and practical opportunities for students from elementary to undergraduate level. Engineering education is relatively new and is still in its early embryo stage in the Singapore education setting. Nonetheless, very few efforts have been dedicated to exploring how engineering practices are being perceived by the local parents [5] as well as investigating the funds of knowledge among the first and continuing generation Singaporean undergraduate students [6]. In the alignment of the Engineering Accreditation Board (EAB), engineering graduates in Singapore are expected to have ethical critical thinking and problem-solving skills to tackle real-world complex problems in the workplace. Ethical issues may arise during the practice of engineering [7]. Given the potential for unethical business practices, academic and industry leaders stress the importance of increasing ethics content in engineering courses [8], for instance, in curricular structures [9]. Course curriculum could benefit from more authentic learning and interdisciplinary teaching focused on ethical engineering design and problem-solving. This is particularly pertinent for engineering education, which is starkly unique from other disciplines [10], and which benefits from framing problem-solving [11]. Engineering design thinking provides value in solving ill-structured complex challenges by re-framing problems in human-centric, ethical ways and centering prototyping and testing. This paper discusses a pilot project. The study incorporates a research-based design thinking framework EDIPT (Empathize, Define, Ideate, Prototype, Test), developed by Stanford University to guide students through conceptualization-to-production processes in a newly designed engineering course at an internationally-renowned university in Singapore.

It is important to help engineering students improve their moral judgment as well as foster their abilities to recognize situations that call for ethical judgment [12]. Such guidance is set within the backdrop of critical ethical engineering studies. Within engineering and in other contexts, privileging rational, convergent inquiry over subjective, divergent thought can limit engineers' attention to important contextual details, with unintended consequences for marginalized

populations [13]. Engineering educators tend to center ethical codes and foreground professional engineers' obligations to employers, clients, practitioners, and society post-licensure [14;15]. However, personal and professional ethics, which are tied to social justice, may be overlooked. Engineering ethics education is incomplete when decoupled from equity [12] - it needs to ensure it is inclusive and does not reinforce inequities, particularly based on demographic variables [16]. Additionally, ethics could be interspersed with contextualized principles [17;18;19] to serve the local public, including marginalized communities.

Findings from design thinking research studies could be integrated into course curricula and other aspects of teaching practice to expand students' learning and practices. For instance, engineering ethics teaching has been shown to provide students with moral reasoning and sensitivity to ethical issues [20]. Students' moral reasoning abilities show higher improvement in a course over a module, suggesting that engineering ethics teaching benefits from being integrative and delivered at multiple points in the curriculum [20;21;22]. Guided by these, for this study, the third-year capstone course for materials science and engineering students were transformed to provide a more authentic learning and interdisciplinary teaching environment for ethical engineering design and problem-solving through the integration of the EDIPT framework. Students worked with industries to tackle real-world problems, with consideration for learning problem-solving in environments relevant to the workplace and focusing on real-world ethical considerations. Industry collaborations also help to narrow the gap between theoretical (e.g., textbook) and practical (e.g., real-world) experiences and challenge students to realistic, authentic problems from industry partners, similar to what engineers face in the real world, with undergirded sensitivity to ethical issues.

This study asks how participants consider ethics within their engineering course. We hypothesize that students applying the engineering design thinking scaffold will experience a more authentic problem-solving experience and gain more confidence and competency in problem-solving with ethical considerations. We also hypothesize that the EDIPT framework will assist students in their real-world projects and beyond the course, and that ethical elements would be considered in varying forms – for instance for the industry, society, and environment.

## II. Significance of the Study

Ethics underpins societal functioning, moral reasoning, and social justice in the engineering field and beyond [*23*]. As technologies related to the engineering profession change and expand rapidly, ethical issues may arise, necessitating knowledge on how to navigate ethical issues in the industry [*24*]. This study aims to equip students for ethical problem-solving, support more innovative and feasible ideas and products, allow students to better exhibit knowledge, and accomplish the Engineering Accreditation Board (EAB) requirements. It simultaneously assesses the applicability of the EDIPT framework in the course curriculum, as well as the impact of design thinking in influencing the engineering industry and problem-solving.

As Asia moves towards global technological and industrial leadership, particularly with Singapore being highly digitally and technologically advanced [25;26] it is important to understand Singaporean engineering indices [27] and Asian professionalism and culture, with the underpinning of ethics. This study contributes to the dearth of research on foreign-based Western frameworks being adopted into Asian contexts. As pointed out in the literature, there is limited research examining the alignment of American-style engineering ethics strategies and cultures of engineering education in Asia [28]. With meritocracy and political neutrality part of the fabric of Singapore's culture, engineers may choose technical over social aspects of the profession [29;30]. Their ideological commitment (to meritocracy and political neutrality) may make it difficult to accept the validity of equity-based decisions [29;31;32;33]. It is thus crucial to assess the integration of ethics in engineering courses, particularly when piloting frameworks, such as design thinking, in the curriculum.

## III. Methodology

### A. Participants

The study was conducted at a world-renowned university in Singapore. 36 third-year engineering students (39% female and 61% male) voluntarily enrolled in a pilot course on Industrial Design, a capstone course. The participants were recruited through convenience sampling, and all provided informed consent. There were no exclusion criteria. Participants attended the course activities such as lectures, group meetings, and coursework in hybrid online/offline form. During in-person classes, they were randomly seated at tables of a maximum of five per table, given COVID-19 regulations, and worked on classroom tasks per table. They had access to the course materials at any time through an online portal and were assigned log journal entries individually and in groups. The six project groups were randomly assigned, with six participants per group. Groups worked with industries to identify real-world problems, conceptualize solutions, and address challenges.

### B. Data collection

The entire project implements an exploratory sequential mixed method research design, with multi-layered research data including student interviews and in-course and post-course reflections. However, this paper focuses on the participants' open-ended pre-course survey responses about ethics in engineering. This was chosen because, after assessing the participants' responses to the quantitative and qualitative pre-course survey, the responses provided depth for qualitative analysis, even within the sample size of 36 participants. The pre-course survey was administered in January 2022 via Google Forms, which participants could fill in their own time prior to the start of the course. The survey consisted of 60 questions, including 10-point Likert scales

and two open-ended questions. 30 participants completed the pre-course survey. The questions on ethics were: "Rate how likely you are to consider ethics in your engineering design," with a 10-point Likert scale option for the response, and "In no more than 50 words, please elaborate on your choice above".

### C. Data analysis

We utilized a qualitative inductive approach [27] to analyze the data. This was chosen as we were interested in the participants' natural and intervention-free views about ethics in their approaches and decision-making. These would consequently be analyzed with the post-course survey, to assess if the course and EDIPT affected participants' views about ethics in engineering. We also wanted to approach the analysis without preconceived notions, nor looking for specific themes. Using an open coding technique, we created descriptive codes to ascertain emerging themes. Inter-rater agreement was reached during the analysis. One author discussed the codes with the other authors, and another author performed coding as well.. The codes were compared and similar codes were grouped and retitled based on coding themes.

## IV. Findings

For the first optional-choice question, participants were asked to rate how likely they were to consider ethics in their engineering design. Figure 1 shows the distribution of responses. Most respondents (73.3%) rated that they are highly likely (≥8/10) to consider ethics in their engineering design. This suggests that ethics is an important factor for participants, potentially beyond their engineering education course.

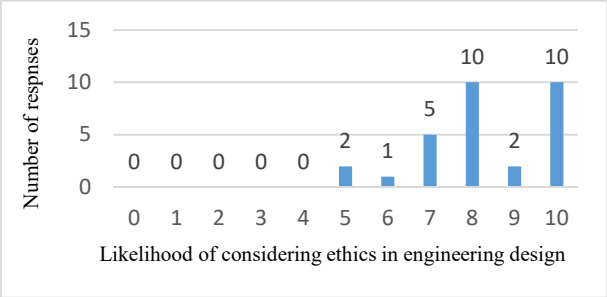


Fig. 1. Responses to the optional choice question

Table 1 shows the distribution and examples of responses to the open-ended question. The table includes selected participant responses (with pseudonyms) as examples. Preliminary analysis suggests five emergent themes of ethical considerations, namely (1) client-centered responsibility (2) intellectual property infringement/ originality, (3) macro ethical considerations, (4) professionalism, and (5) others. (1) refers to designing and creating products with the client's needs in mind, (2) refers to not copying other designs, (3) refers to environmental, sustainability, and other larger-scale considerations, and (4) refers to professional standards when performing their work.

From the findings, we can see that participants have a variety of definitions of ethics in engineering. Most responses (25-27%) focus on professionalism and client-centered responsibility, for instance, fulfilling customer requirements through a human-based and user-friendly problem-solving approach. This suggests that participants may be more likely to attend to the customer rather than focus on social justice or marginalized populations, as discussed in the introduction. It highlights the need for ethics to be taught in a balanced way in the course curriculum.

TABLE I. Responses to the open-ended question

| Theme | Frequency of code | Examples |
|---|---|---|
| Client-centered responsibility | 16/60 (27%) | *"The fundamental requirement of an engineering design is to fulfill the customer requirements […] human-based and user-friendly issue should be considered"- Qihui*<br>*"Ergonomics and anthropometry has to be considered while making the product to ensure that it is safe and comfortable" – Ping Xie* |
| Intellectual property infringement/ originality | 10/60 (17%) | *"Do not copy other's designs." - Jei Ru*<br>*"To be as original with my idea as possible"- Kiat Han* |
| Macro ethical considerations | 11/60 (18%) | *"it is imperative that the products/designs are safe for both humans and the environment. System or part failure may lead to ecological and economic disasters."- Marc*<br>*"balance the virtues of environmental ethics against costs, where general manufacturing of common materials have negative impacts on the environment."- Andy* |
| Professionalism | 15/60 (25%) | *"the product that was created by me should have a certain standard before presenting it to respective superiors."- Kay Seng*<br>*"to fulfill the customer requirements, so in my opinion human-based and user-friendly issue should be considered prior than business consideration." - Qihui* |
| Others | 9/60 (15%) | *"I will try to consider ethics in the design but am not too sure if I will be able to implement it effectively"- Rebecca*<br>*"Motivated in this interesting module with slight anxiety." - Ahmed* |

Responses also discuss intellectual property infringement/originality (17%), suggesting that for some, ethics means not copying others' designs and being original with engineering ideas. Some responses also discuss macro ethical considerations (18%), indicating that ethics involves sustainability and ecological and environmental considerations. Some responses fell into other categories (15%), with no clear definition of ethics or about how to incorporate it into the engineering work. Through the EDIPT framework, participants may gain a more explicated and nuanced understanding of what ethics in engineering entails.

There is a limitation regarding the data and analysis. The data is in the preliminary stages and further data collection and analysis are being conducted. Thus, it is hard to ascertain at this point to what extent the course has affected participants' views about ethics in engineering.

## V. Educational Implications and Discussion

Other studies focused on engineering ethics incorporate and assess ethics in a varied way from our project. For instance, studies may explore ethics incorporated as an intervention into the curriculum [2;9]. In contrast, our study looks at participants' natural, non-intervention views on ethics and whether these change or evolve throughout the study. It is also valuable to understand participants' varied understandings of ethics in engineering, and how and to what extent it would be incorporated into their professional lives.

As industries evolve quickly, particularly in Asia, and new technologies are introduced to the market, the underpinning of ethics should be taught in the curriculum, so that students will assess ethics independently beyond the classroom. It is of interest to assess if participants develop a sense of control over technologies and agency over problem-solving [9].

The codes that emerged from the data are consistent with the literature. Other studies also discuss client-centred responsibility [28], macro-ethical considerations [29], and professionalism [30]. These suggest that ethical considerations in engineering extend across a variety of countries and cultures. As this form of analysis has not been conducted in a Singapore context, this study contributes to a better understanding of students in Singapore's and Asian approaches and considerations regarding ethics in engineering. The findings also support the standardized EAB criteria, which highlight ethics as a crucial underpinning in engineering.

Continued studies focused on contextualized localities, such as this study, provide depth and breadth to the research on ethics in engineering. It also delves into the theoretical implications of research-based frameworks in various contexts and settings. Implementing the EDIPT framework is not just about analyzing generalizability, it is also about assessing a theoretical framework in a practical setting.

## VI. Conclusion

Engineering design thinking provides value in solving ill-structured complex challenges by re-framing problems in human-centric, ethical ways and centering prototyping and testing. Findings from design thinking research studies could be integrated into course curricula and other aspects of teaching practice to expand students' learning and practices.

Student understanding and application of ethics have implications on the EAB requirements as well as graduates' approaches to industry solutions. The formation and interpretation of data codes were based on the theoretical framework afforded by theories on ethics in engineering, and how participants understand ethics in the context of schooling and course norms and practices. Findings from this study will help to bolster the research on ethical considerations in design thinking for the engineering field, as well as the applicability of foreign research frameworks in local practice contexts. Findings will also support determining the best approach for improving the teaching framework for future iterations of the engineering courses, as well as assessing the suitability of applying design thinking to similar capstone courses within the university.

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