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Exploring Client Perceptions of Incorporating Societal Implications in Engineering Design Projects

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Abstract

This Academic Practice/Design Intervention full paper submission presents the results of an open-ended survey which explored clients' perceptions of the process used to create project topics that require students to consider the broader societal implications of their designs.

Client-based pedagogy in engineering design courses offers students the opportunity to apply theoretical knowledge to real-world contexts. Beyond exposure to practical problems, the integration of societal considerations into engineering design education is increasingly recognized as crucial for cultivating socially responsible engineering professionals.

This study analyzes survey data collected from 12 clients participating in a first-year, community-engaged learning course at a Canadian, medium-sized, research-intensive institution to understand their perspectives on engaging students with complex, real-world challenges. Clients iteratively collaborated with instructors to develop project descriptions, ensuring projects met technical requirements while prompting students to consider factors beyond traditional engineering constraints. Utilizing an inductive coding approach, emergent themes include the perceived value of exposing students to societal impact considerations, challenges faced by clients in formulating project topics that effectively integrate these considerations, and perceived benefits for student learning and skill development.

This research contributes to the nascent body of literature addressing client-based pedagogy within engineering education by highlighting the critical role of client-instructor collaboration in developing project topics that prepare future engineers to address complex societal challenges. The findings offer practical implications for curriculum development and the cultivation of impactful partnerships between industry and academia in engineering education.

Introduction

In today's rapidly evolving and increasingly interconnected global landscape, the responsibilities of engineers transcend mere technical competencies related to design and implementation; rather, they encompass a significant and profound obligation to thoughtfully consider the various societal implications that stem from the work they undertake. As we look towards the future and recognize the critical role that undergraduate students will play as emerging leaders in the engineering profession, it becomes imperative that they are not only equipped with the essential technical skills necessary for success but are also imbued with a keen awareness of how their projects will impact a diverse array of stakeholders and the larger community in which they operate.

This research paper aspires to delve deeply into the perspectives and expectations of clients regarding the vital integration of societal implications into the project descriptions that students

encounter within an engineering design course, thereby shedding light on a crucial aspect of the educational experience. By comprehensively understanding the expectations and insights of clients, we can significantly enhance the educational framework designed for engineering students, ensuring that they emerge not only as technically proficient professionals but also as individuals who are adept at recognizing, understanding, and addressing the social, ethical, and environmental consequences that their designs may elicit.

Background Review

Socio-Technical Thinking

In recent years, engineering educators have been incorporating socio-technical thinking as part of their courses. Conventional engineering education frequently emphasizes technical competencies, which may result in a deficiency in students' cognizance of the extensive ramifications of their endeavors on society. Socio-technical reasoning synthesizes both technical and non-technical aspects, acknowledging that successful engineering solutions necessitate a harmonious integration of both facets to effectively confront intricate societal issues. This methodology underscores the importance of comprehending the societal context and repercussions of engineering endeavors, encompassing ethical, environmental, and cultural dimensions [1].

Students often struggle to recognize the importance of non-technical aspects, such as stakeholder involvement and ethical considerations, which can result in simplistic views of complex problems [2]. As such, experiences with stakeholders and communities need to be scaffolded and curricular intentions need to be explicit. Bilow and DeWaters [2] suggest incorporating socio-technical thinking into existing engineering courses, ensuring that students engage with real-world problems that require consideration of social, ethical, and environmental factors. This integration can help students see the relevance of non-technical aspects in their work and have positive impact on their professional identity. Another effective pedagogical strategy is to use case studies that highlight successful engineering projects where socio-technical considerations played a crucial role [3]. Analyzing these examples through systems thinking can help students understand the impact of non-technical factors on project outcomes [4].

Design Pedagogy to Teach Socio-Technical Thinking

Engineering design courses encourage a comprehensive approach to problem-solving by integrating technical and social dimensions. Effective engineering design involves collaboration with various stakeholders, ensuring that their perspectives and needs are considered. This engagement fosters reflective practice, empathy and a deeper understanding of the social implications of engineering solutions [5]. In addition, the iterative nature of engineering design allows for continuous feedback and adaptation. By revisiting and refining designs based on stakeholder input, engineers can better address non-technical aspects and improve project outcomes.

Real World Relevance in Design Courses

Both socio-technical thinking and engineering design experiences are best realized when the design challenges are authentic. Such authenticity can be found in real-world problems. Engaging with real-world problems allows students to develop critical problem-solving skills that are essential in professional engineering practice. This experiential experience helps them navigate complex, ill-defined challenges similar to those they will face in their careers [6] and may promote motivation in learning [7]. Also, real-world problems often require knowledge from various disciplines, promoting interdisciplinary collaboration. This exposure helps students appreciate the interconnectedness of engineering with other fields, such as social sciences and environmental studies [8]. Finally, addressing real-world issues encourages students to consider the ethical implications of their engineering solutions, instilling a sense of social responsibility and awareness of the impact their work has on society [6].

Engaging Clients in Design Courses – Client-Based Pedagogy

Client-based pedagogy encompasses an educational framework wherein students actively participate in real-world projects that necessitate interaction with actual clients to resolve actual challenges. This pedagogical strategy cultivates an enhanced sense of ownership regarding projects, promotes experiential learning, and amplifies student motivation through the provision of authentic tasks and environments [9]. The primary objective is to bridge the divide between theoretical classroom instruction and practical professional application, thereby enabling students to acquire experiential knowledge and familiarity with the content, methodologies, and contexts pertinent to their prospective careers, ultimately augmenting their problem-solving and communication competencies.

Also, client-based pedagogy necessitates that students collaborate with genuine clients to address defined briefs, thereby nurturing practical problem-solving abilities and collaborative skills [10]. This approach facilitates the development of students' creative identities and the application of skills within a nurturing environment, with a pronounced emphasis on negotiation and the assumption of professional roles through iterative cycles [11]. Through engagement with clients, students cultivate the ability to navigate expectations and establish work ethics, thereby enhancing their autonomy and emotional investment in the educational experience.

While it offers valuable real-world experiences, client-based pedagogy may inadvertently create challenges. The emphasis on collaboration with clients can overshadow the essential theoretical foundations that underpin professional practice. Students might prioritize client satisfaction over deepening their understanding of core concepts, leading to a superficial grasp of the subject matter [9]. This could ultimately weaken their academic foundation, as they might not fully engage with the theoretical frameworks that inform effective practice in their fields [12].

In this interplay, often the clients' perceptions are overlooked in the entire process. Maitra and Erway [13] highlighted that clients have mixed perceptions about their role as active participants

in client-centered practice and were unaware of the pedagogical value of such approaches. Clients may perceive client-based pedagogy as lacking involvement in decision-making, insufficient information, and services misaligned with their needs. Hence partnerships need to be transparent and guided by educators and educational developers to influence a positive interaction with students leading to future collaborations and internships, benefiting both students and the client organization [14].

Methodology

Context of Study

This study examines client perspectives on the socio-technical components of a first-year client-based design course at Smith Engineering, Queen's University, Kingston, Ontario, Canada. In 2024, Smith Engineering released a new strategic vision focused on "Reimagining Engineering Education." One of the key pillars of this strategy is focused on "Engineering for Humanity," ensuring that students consider the societal and environmental impacts of their designs.

The course, APSC 103: Engineering Design, is conducted during the winter semester of the first year and has an enrollment of approximately 1,000 students. It represents the first opportunity for students to engage in a client-centered design project. Each year, there are between 30-40 unique client projects, with several 4-5 person design teams assigned to each project.

During the summer prior to each academic year, a letter is sent to prospective clients to solicit project ideas for APSC 103. Historically, this letter emphasized the technical aspects of engineering design and the client's expected deliverables. For example, previous letters included statements such as: "Attempt to quantify your problem by giving at least three measurements and design specifications that will be important to solving your problem." However, a new solicitation letter was developed to incorporate a focus on the societal considerations of the projects. Clients were asked to "incorporate a systematic inclusion of social science and humanities knowledge in their proposed project descriptions."

This new approach resulted in clients providing a broader range of suggestions regarding the potential social impacts of their projects. However, many initial submissions were very general in nature. After receiving these initial submissions, the institutional team worked with the clients, offering more detailed explanations of "Engineering for Humanity" and the types of broader social and environmental impacts to be considered. Below are two examples of project descriptions provided by clients, illustrating this collaborative refinement process:

Example 1

Initial Project Description: “This project addresses a real-world application to improve emergency services and assist firefighting personnel. The project contributes to a larger scale in improving emergency services and conserving the strength of firefighters in active duty.”

Refined Project Description: “This project focuses on taking a humanistic approach to better society and community. While the scope of this project revolves around high-intensity emergency situations, it can be expanded to include assistance for people with physical disabilities. By understanding the use case, students will create a device that can be applicable to many purposes and sectors of the community. This project should also encourage students to think about life-cycle design, material selection, energy efficiency, and durability of the device.”

Example 2

Initial Project Description: “We hope you can use your engineering skills to iterate your way to a complete concept, that will enable us to develop the transportation of tomorrow. You will have the opportunity to visit our design bay and see our technology, gaining valuable experience and learning from knowledgeable team members. You will be able to guide your own way through the project and arrive at a solution you believe is best!”

Refined Project Description: “Students should consider the bigger-picture impact of high-level transportation and environmental factors when working on this project. The Hyperloop mission statement says: ‘We don’t sell cars, boats, trains, or planes. We sell time. We’re creating a seamless experience for a passenger that starts the moment you think about being somewhere – not going somewhere. Door to door faster than ever before.’ There are a variety of larger positive and negative impacts that need to be considered when looking at high-level transportation. Positive impacts include reduced travel time, decreased traffic congestion, and more. Negative impacts include high costs, possible land displacement, and more. Lastly, students should consider how high-level transportation affects urban planning and urban design.”

These examples illustrate the types of societal and environmental impacts that the clients outlined for their projects. In previous years, such content was not explicitly included in the course. Through changes to the project solicitation process and collaboration with the instructional team, clients were able to develop project descriptions that encourage students to consider the broader societal [1] implications of their designs.

Survey Design and Analysis

To gather data on client perspectives regarding the inclusion of societal considerations in design projects, an online survey was developed and administered on Qualtrics Survey. The survey comprised a combination of Likert-scale items and open-ended questions. The Likert-scale items

explored the perceived importance of societal considerations, their impact on design outcomes, and the challenges of integrating them into design processes. The open-ended questions delved into the specific impacts observed by clients, how societal considerations may influence the final designs, and any overlooked societal issues. The survey was distributed to 16 clients who participated in the engineering design course. The survey was distributed to the clients via email in which a motivation for the study was included and they were reminded of the initial project description and the final description which was a product of a few iterations. 87% of the clients responded and participated in the survey.

The quantitative data from the Likert-scale items were analyzed using Spearman's rank-order correlation to examine the relationships between different aspects of societal consideration integration. The qualitative data from the open-ended questions underwent thematic analysis to identify key themes and patterns in client responses.

Participants

As the course serves the entire first year engineering cohort, projects are sourced from various types of industries. The breadth of industries helps increase students' awareness of the different kinds of engineering tasks present in society. Table 1 shows the distribution of the industries the participants came from.

Table 1 Distribution of types of industry of participants

Industry	Number of Participants
Academia	2
Mechanical Engineering	2
Retail	1
Govt Services	3
Educational Services	2
Biotechnology	2
Computer Engineering	1
Space agency	1

Findings

The survey data was analyzed to understand how clients for a first-year engineering design course perceived the expansion of design briefs to include more socio-technical considerations. Due to a small sample size, only descriptive analysis and non-parametric tests were conducted to find any relationships between variables. We used thematic analysis to draw insights from the open-ended questions.

Descriptive Analysis

Clients were asked if they saw any value in considering societal implications when framing a design problem. This question helped the authors to understand clients' orientation towards socio-technical thinking. As shown in Figure 1, most respondents (93%) consider the inclusion of societal implications in design problems to be very important or extremely important. This finding helps us to understand the data generated by other survey questions as it was evident that these participants all agreed that considering societal implications was an important aspect of the design process.

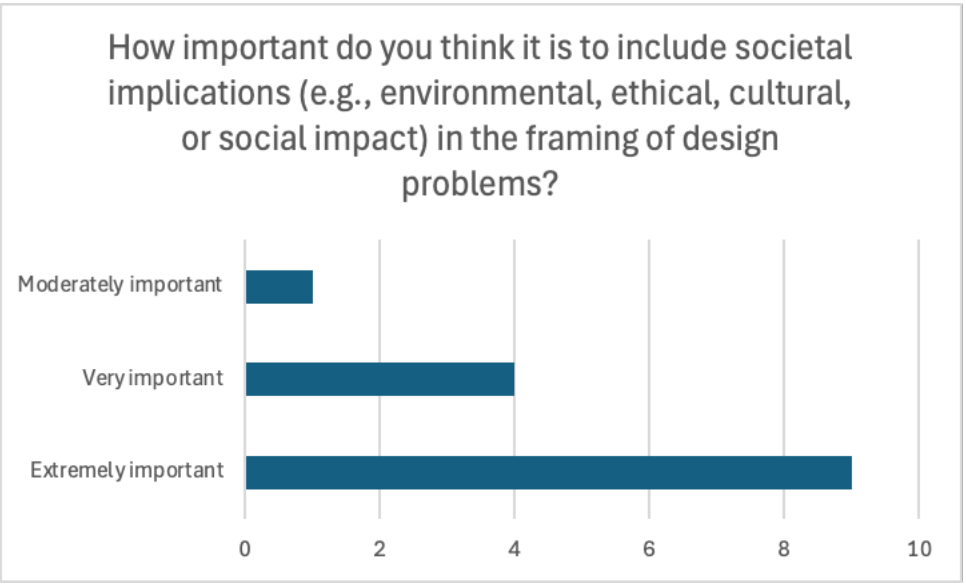

Figure 1 – Clients' perceptions on considering societal implications when framing a design problem

Next, clients' focus was brought to whether the design problems in the course were framed in a way that would allow students to consider societal implications when generating design requirements. The responses to this question are more evenly distributed, with a slight majority (50%) somewhat agreeing that societal implications were effectively integrated as shown in Figure 2.

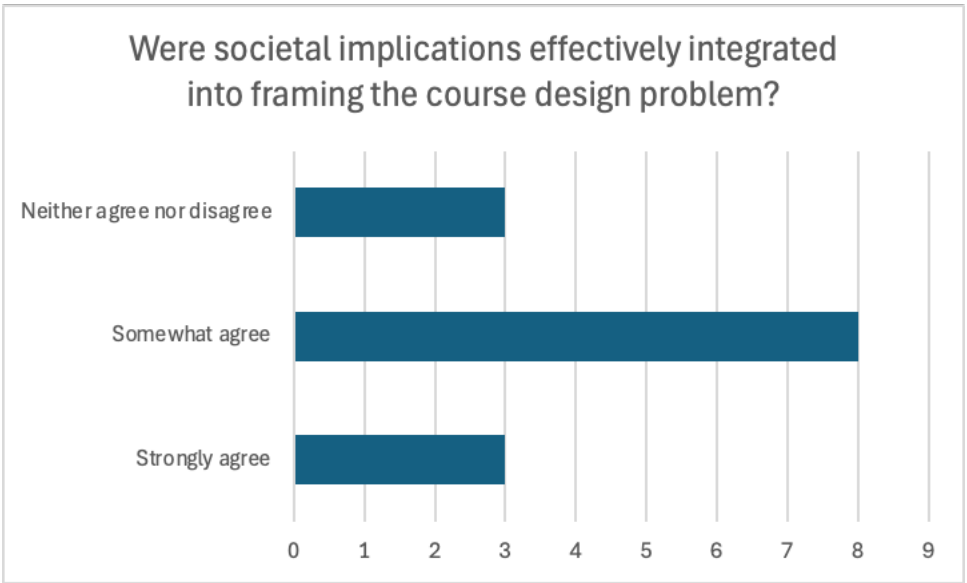

Figure 2 – Clients' perceptions on the quality of integration of societal implications in the design problems for the course

We asked clients if they thought changes to their initial design descriptions would impact on the final designs that students deliver at the end of the course. To this question, the vast majority of respondents (93%) believe that including societal implications in the design problem will impact the final design, with most (64%) indicating a probable impact, shown in Figure 3. This finding indicates that the changes in the framing of the design problems will have an influence on what students consider and create for their design projects.

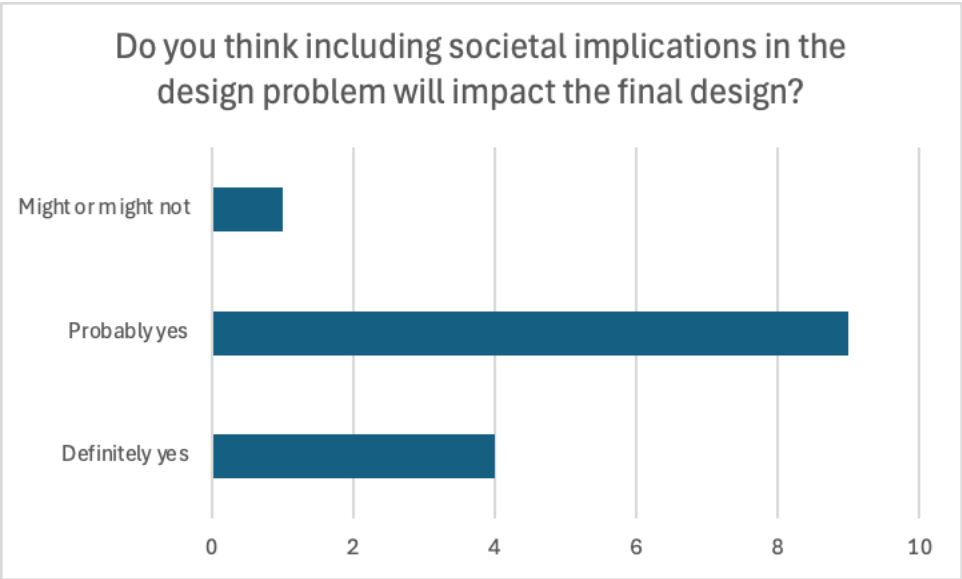

Figure 3 – Clients' perceptions on the impact of integrating of societal implications on students' final designs

As clients were situated in different industries, they were asked if considering societal implications of their work required in their industry. As shown in Figure 4, the majority of the respondents (72%) believe that socio-technical thinking or understanding societal implications is required in their industry, with 43% definitely agreeing.

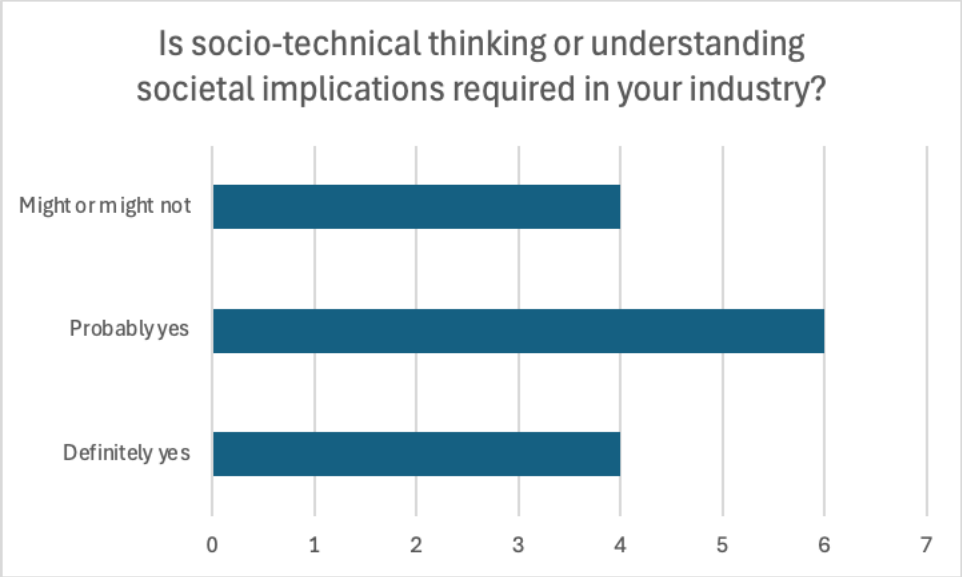

Figure 4 – Clients' responses to whether considering societal implications in their industry is a requirement

Finally, clients were asked if they found it challenging to incorporate societal considerations into their design problems for the course. Most respondents (57%) did not find it difficult to identify relevant societal factors, with 21% strongly disagreeing that it was difficult.

Inferential Analysis

We conducted non-parametric tests on clients' responses to understand if there were any relationships between clients' perceptions of including societal considerations with respect to their own beliefs, the nature of the course, and the industry they belong to.

A Spearman's rank-order correlation was conducted to examine the relationship between the perceived importance of including societal considerations in design problems and the perceived impact of these considerations on the final design. The correlation was positive and statistically significant, $r_s(14) = 0.60$, $p = 0.023$. This strong correlation shows that participants saw the value of expanding their design problems for the course. The statistically significant result may indicate participants' willingness to work with the instructional team in providing authentic design problems.

When connecting participants' beliefs with anticipated outcomes, there was a strong positive relationship. A Spearman's rank-order correlation showed that the relationship between perceived

effectiveness of integrating societal implications into the framing of the course design problem and the perceived impact of including societal implications on the final design. The correlation was positive and statistically significant, $r_s(14) = 0.576$, $p = 0.031$. This finding indicates that participants not only see value in integrating societal considerations but are somewhat confident that the new design problems will yield final designs different from the initial design problems.

Although the other analysis showed weak relationships and the results were not statistically significant, the findings may indicate some insights about the clients' perceptions. The Spearman's rank-order correlation for the relationship between the perceived importance of including societal considerations in design problems and the perceived effectiveness of integrating societal implications into the framing of the course design problem was positive, $r_s(14) = 0.496$, $p = 0.071$, but not statistically significant. Also, a Spearman's rank-order correlation was conducted to examine the relationship between the necessity of socio-technical thinking in the respondents' industry and the perceived impact of including societal implications on the final design. The correlation was positive but not statistically significant, r_s(13) = 0.319, p = 0.266. Both these findings suggest that clients may be hesitant to label the project description as an effective integration without interacting with the students across the term and analyzing their final designs. Also, drawing a relationship between academic design projects for first-year students to industry standards may seem like a stretch for clients without observing the impact firsthand at the end of the term through final designs.

Thematic Analysis

There is a general consensus among participants that including societal implications in framing design problems is important. Participants recognize the value of considering a broader range of stakeholders and potential impacts beyond the immediate technical specifications of a design.

Impact on Design Outcomes:

Participants believe that incorporating societal considerations influences the final design. This impact can manifest in various ways, such as the choice of materials, the functionality of the design, and the target demographic. Some participants noted that considering societal factors could lead to more complex and potentially costly solutions, but they emphasized that these considerations are necessary for real-world applications.

Challenges and Overlooked Issues:

Some participants identified challenges in integrating societal considerations, such as the potential to deflect from technical work if not done well. A few participants noted specific

societal issues that were overlooked or not adequately addressed in the design projects, including environmental concerns and engagement with Indigenous communities.

Benefits for Students:

Participants highlighted the benefits of incorporating societal considerations for engineering students. These benefits include developing critical thinking skills, understanding real-world problem-solving, and considering the broader impacts of their designs.

Discussion & Implications for Engineering Design Education

This study examined client perspectives on the integration of societal considerations in engineering design projects within an educational setting. The quantitative analysis revealed significant positive correlations between the perceived importance of societal considerations and their perceived impact on the final design ($r = .60$, $p = .023$), as well as between the perceived effectiveness of integrating societal considerations and their perceived impact ($r = .58$, $p = .031$). These findings suggest that when clients view societal considerations as important, they also perceive them to have a greater influence on design outcomes. This aligns with previous research emphasizing the importance of stakeholder perspectives in shaping design solutions and the recognition that societal factors play a crucial role in design success [15].

An interesting insight from the quantitative analysis showed that clients showed stronger relationships between their beliefs about societal implications and the impact it will have on final student design projects. However, the relationship was weaker when comparing the relationship between the necessity of socio-technical thinking in the respondents' industry and the perceived impact of including societal implications on the final design. The difference in the strength of the relationships may suggest clients may consider student design projects as not fully representative of what their industry requires out of design framing. In other words, the importance placed on societal implications in design problems does not necessarily indicate a strong connection to the perceived need for socio-technical thinking in the respondents' respective industries.

Furthermore, the qualitative analysis identified several key themes. Clients highlighted the benefits of incorporating societal considerations for student learning, including the development of critical thinking skills, real-world problem-solving abilities, and a broader understanding of design impacts. This resonates with studies advocating for the integration of societal considerations in engineering education to foster responsible and ethical design practices [16]. However, clients also pointed out challenges, such as the potential for societal factors to deflect from core technical work if not managed effectively, and the need to address a wider range of societal issues, including environmental concerns and engagement with Indigenous communities.

These challenges underscore the importance of providing adequate support and guidance to students when integrating societal considerations into design projects.

Despite these challenges, the overall positive perception of the importance and impact of societal considerations suggests a growing recognition among clients of the need for engineers to consider the broader societal implications of their designs. This aligns with the increasing emphasis on socio-technical thinking in engineering practice, where technical expertise is intertwined with an understanding of social and ethical contexts.

The findings emphasize the importance of embedding societal considerations into engineering pedagogy, particularly during the project definition phase, ensuring these factors are integral from the outset of the design process. This approach, as reflected in client feedback, not only prepares students to engage with real-world complexities but also enhances the authenticity and relevance of client-based projects. By framing design challenges with explicit societal dimensions students are better equipped to develop solutions that address multifaceted, real-world problems. The significant client consensus on the influence of societal factors suggests that incorporating these elements early fosters deeper student engagement and strengthens their ability to navigate the socio-technical complexities of engineering practice. This alignment of pedagogy with real-world societal challenges underscores the transformative potential of client-based projects to instill a sense of responsibility and empathy in engineering students.

Future research could delve deeper into the specific pedagogical approaches and support mechanisms that best equip students to effectively incorporate societal considerations into their designs. Additionally, investigating the interactions between the clients and students when negotiating societal considerations to influence not only the final design but also the design process itself could yield valuable insights.

Limitations

This study has some limitations that are important to acknowledge. First, the sample size of 14 clients is relatively small, which may limit the generalizability of the findings to a larger population of clients. Second, the clients represented a variety of industries and had varying levels of industry experience, which could introduce variability in their understanding and perceptions of societal considerations in design. Future studies with larger and more homogenous samples could provide further insights into the relationship between client perspectives and the integration of societal considerations in design projects.

Conclusion

This study highlights the importance of embedding societal considerations in engineering design education. Clients perceive significant value in incorporating societal factors into design projects, recognizing their influence on both student learning and design outcomes. As socio-technical thinking develops with time and experience, it is imperative educators introduce such

thinking early in the curriculum. This inclusion allows engineering programs to equip students with the skills and awareness needed to address complex societal challenges and contribute to a more responsible and ethical engineering practice. The findings underscore the transformative potential of client-based projects to not only enhance technical proficiency but also instill a sense of social responsibility and empathy in future engineers.

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