Equipping students in software development with socially engaged engineering and design skills

Dr. Jin Woo Lee, California State University, Fullerton

Dr. Jin Woo Lee received his Ph.D. and M.S. in Mechanical Engineering from the University of Michigan, and B.S. in Mechanical Engineering from Binghamton University. Dr. Lee's research focuses on design theory and methodology, product design, and engineering education.

Paul Salvador Bernedo Inventado, California State University, Fullerton
Dr. Erika Mosyjowski, University of Michigan

Erika Mosyjowski is the Research and Faculty Engagement Manager in the Center for Socially Engaged Design within University of Michigan College of Engineering. She earned a PhD and MA in Higher Education from Michigan and a Bachelor's in Psychology and Sociology from Case Western Reserve University.

Equipping students in software development with socially engaged design skills

Abstract

There is an increased awareness that designers who develop technologies often do not possess the skills to successfully engage with communities, identify context-specific needs, and create solutions that address those needs. To address this gap, the Center for Socially Engaged Engineering and Design at the University of Michigan developed the Social Engagement Toolkit (SET), a library of training on various topics related to socially engaged design practices. At a minority-serving institution, several workshops from the SET were implemented to support a semester-long, extra-curricular project experience for students majoring in Computer Science who aimed to design software solutions to address real-world problems. SET workshops on several topics, including Introduction to Socially Engaged Design, Crafting Need Statements, Ecosystem Stakeholder Mapping, Interviews, User Requirements and Specifications, Idea Generation, and Concept Selection and Prototyping were used to provide scaffolding for students' design projects and teach critical skills that are not often emphasized in the traditional curriculum. Student reflection and exit survey data examined student learning experiences along with the challenges of implementing skills they have learned. Students described the benefits of learning an effective socially engaged design process to plan their projects, engaging with stakeholders to gather important information regarding their needs, learning recommended practices in idea generation, and creating prototypes before coding. On the other hand, students described perceived challenges including lacking experience in socially engaged design skills that may impact their ability to implement skills from the workshops effectively, identifying and connecting with stakeholders who could provide meaningful information, and translating and prioritizing stakeholder data into requirements and specifications for their projects. This study demonstrated the overall process of implementing the SET to support students engaging in software development and examined students' experiences.

Introduction

It is increasingly recognized that engineering solutions must be technically sound and feasible while also accounting for the human, cultural, economic, and environmental factors when designing technology (Palmer et al., 2011). Engineers' and computer scientists' work should be *for* the benefit of people and society. Professional societies such as the National Academy of Engineering emphasize service to society as a core mission of engineering (National Academy of Engineering, 2015). However, engineers who work *for* people but not effectively with people in terms of stakeholders and communities by considering their social context risk perpetuating existing social inequities (Nieusma & Riley, 2010). Engineering and computer science students need to be trained in design practices that consider social and cultural factors to ensure that their designs promote inclusive and equitable outcomes.

To address the need to better prepare students to account for social and contextual dimensions of their work, the Center for Socially Engaged Engineering and Design at the University of Michigan created the Social Engagement Toolkit (SET). The SET is a collection of resources and lessons on a variety of socially engaged engineering topics (*Center for Socially Engaged Design*, n.d.; Mosyjowski et al., 2023). The SET workshops were implemented at another large institution for a semester-long extracurricular learning experience along with workshops on

recommended practices in software development. These workshops guided students in developing software solutions to problems they have identified and provided scaffolding in their design. This study examined student feedback on the benefits and challenges of implementing the content from the workshops.

Background

Need for Socially Engaged Design Skills

There is a growing recognition that engineers need to have the skills necessary to account for the social and contextual factors of design problems (Kouprie & Visser, 2009; Palmer et al., 2011). A balance between technical and social skills and the need for a more holistic approach to engineering education has also become central to the ABET criteria (ABET, 2019). Accounting for human and contextual factors involves co-creating solutions by incorporating the input of the people and communities that will use them. We refer to these skills as socially engaged design skills. Training in socially engaged design can lead to inclusive and equitable design decisions that promote the adoption of technology because it better meets the needs of its users (Kouprie & Visser, 2009).

Despite the merits of socially engaged design, engineering and computer science curricula often underemphasize social and contextual dimensions of engineering work (Lattuca et al., 2014). Students may not be equipped to successfully engage with communities, identify stakeholder- and context-specific needs, and create solutions that address those needs. The result is a disconnect between technology designers and users, resulting in often well-intended designs that suffer from negative consequences (Howitt et al., 2012). For example, Airbnb, which provides a way to find feasible and cost-effective accommodations for travelers, has led to inequitable experiences for certain populations of users. In 2015, researchers conducted a study on Airbnb and found that accounts with distinctly African-American names were less likely to receive a positive response to their requests (McPhate, 2015). The field has numerous case studies demonstrating the consequences of technology that did not consider social contexts during their design and implementation (Wood & Mattson, 2016).

Social Engagement Toolkit (SET)

The Center for Socially Engaged Engineering and Design (C-SED) promotes a "humanity-centered" approach that aims to prepare engineers to "consider broad contexts through an equity-centered lens that impact the practice of engineering, including social, cultural, political, economic, and environmental factors that can completely change the design of solutions." C-SED developed the SET as a means of supporting educators in helping students develop the skills and knowledge necessary to account for social and contextual dimensions of engineering work. The SET includes instructional materials on a wide range of topics including the socially engaged design process model, problem definition and needs statements, requirements and specifications, stakeholder mapping, concept selection, prototyping, design interviews, managing power and identity in design, and a variety of sociotechnical case studies. The SET content is grounded in research and has been developed by a team with expertise across many dimensions of engineering, design, and education.

The SET content is intended to be adaptable to a variety of educational needs and contexts, both within and outside the classroom. SET modules can be implemented as in-person or virtual

synchronous workshops or online hybrid learning blocks, which combine asynchronous online learning with coaching. The in-person workshops can be customized to meet the course objectives and C-SED offers both facilitation by highly trained graduate students and staff facilitators or support for instructors to teach the content in their courses. The online hybrid approach is designed to guide students through prior knowledge reflection, provide foundational knowledge through readings and videos on diverse topics, and offer assessments of student understanding at the end. Students can then take their new skills and apply them through real-life engineering case studies or project experiences and receive feedback. Prior research has demonstrated that the SET hybrid learning block approach can support students in adopting recommended practices and developing their skills related to interviewing stakeholders, generating ideas, and selecting concepts, among others (Lee et al., 2018, 2023; Loweth et al., 2020; Strehl et al., 2022). For example, a study examining student idea generation practices using the SET content showed that students adopted more recommended practices after going through the learning experience and they were able to apply strategies they had learned in their design practice (Lee et al., 2023).

Study Design

We developed a semester-long, extracurricular software development opportunity for students using a combination of SET modules and software development modules. In this study, we examined the following question:

What are the benefits and challenges of incorporating the SET modules for students working on software development projects?

Participants

During Fall 2022, all participants went through a competitive application process to ensure the most productive learning environment. A total of 107 students applied to participate and 33 students were interviewed. In the end, ten upper-level students majoring in computer science were selected for the program (as shown in Table 1), and each student received a $2,500 fellowship to lessen financial burdens. A technology company provided student fellowships. Students were required to participate during Spring 2023 (16 weeks) and commit approximately 8-10 hours a week. Student teams were mentored by two faculty members to ensure that students received a quality learning experience.

Table 1. Participant information

Pseudonym	**Gender**	**Ethnicity**
Abbie	Non-binary	Non-Hispanic white
Bella	Female	Asian
Chris	Male	Asian
David	Male	Latinx
Esteban	Male	Latinx
Faith	Female	Asian
Gabriel	Male	Latinx
Hailey	Non-binary	Asian
Irene	Female	Non-Hispanic white
Jorge	Male	Latinx

Students were divided into two teams (5 students per team) to identify and develop possible solutions for problems. One team worked with people with disabilities to understand their needs and identified that their stakeholders experienced difficulties navigating public spaces. They developed a platform that aims to create a nationwide disabled-led review site for ADA compliance of local businesses. Another group worked with transgender individuals to identify needs and discovered that these individuals face unique health disparities that cause both physiological and psychological harm. As the transgender community becomes more visible, there is a growing demand for accessible and affordable gender-affirming healthcare products and services. They developed an application that serves as a comprehensive platform for transgender medical resources and patient information.

Workshops

The extracurricular experience involved weekly meetings with students that required them to identify a problem and ultimately develop a software solution at the end of the semester. Workshops were provided each week to provide scaffolding for their project (as shown in Table 2). After presenting both the SET and software development modules, the last several weeks of the semester were dedicated to team meetings and software development. All workshops were presented to students in weekly meetings in person.

Table 2. List of workshops presented to students.

	Workshop Topic	**Learning Objectives**
SET Modules	Introduction to Socially Engaged Design and Need Statement	Describe the 5 stages and undercurrents of the Socially Engaged Design process model. Define stakeholder needs and craft need statements.
	Stakeholder Mapping	Describe the range of stakeholders who may be affected by the project Create a stakeholder map that accounts for a variety of ecosystem categories/stakeholder types.
	Interviews	Define the goals of a design interview. Recognize what goes into planning and conducting an interview.
	Requirements and Specifications	Describe the differences between needs and requirements. Describe the process of identifying requirements. Differentiate between requirements and engineering specifications. Translate requirements into their corresponding specifications.
	Idea Generation	Understand and apply guidelines needed to successfully generate ideas. Use a variety of ideation strategies and tools.
	Concept Selection and Prototyping	Better understand the positives and negatives of their ideas. Learn about different prototypes and how to use them to advance the project.
Software Development Modules	High-Fidelity Prototyping for Software Development	Design the user interface and user flow for using the application. Quickly generate an interactive application to get early user feedback.
	Git Workflow	Track, manage, and coordinate collaborative software development.
	Unit Testing	Ensure code quality through automated continuous testing.

Data Collection and Analysis

To examine how the semester-long experience impacted students, we regularly requested students to reflect on the learning experience. After each SET lesson, we asked the following four reflection questions:

- What is/are the most important concept(s) you have learned?
- How will you use the skills you have developed from this workshop for your project?
- What might be the challenges or barriers to implementing ideas from this workshop?
- What support would be helpful to have in implementing ideas from this workshop?

At the end of the semester, an exit survey was conducted with the following questions:

- What was the most useful thing you have learned from this experience?
- The workshops covered information I anticipate I will use in my future academic or professional career on a 5-point scale (strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, and strongly agree) with the list of all workshops.
- What were the workshops that helped you the most for the project? Why?
- What changes would you like to see to the workshops?
- What kind of support would have been beneficial?
- Are there particular topics that you would have liked to have seen covered more or less?
- Would you recommend this experience to other students? Why or why not?

One team member led the data analysis of qualitative data by reading through all reflection questions and noting themes from the responses. While we report student ratings of both the SET and software development modules, the main focus of this paper is on the SET workshops and outcomes. These themes were then iterated and grouped into two categories: 1) the benefits of the SET content for their projects and 2) the perceived challenges of utilizing the SET content for their projects. For example, a theme of "engaging with stakeholders" was added within the benefits of the SET content for their projects as students repeatedly emphasized the importance of understanding the needs of stakeholders and receiving feedback to make progress on their projects. For the quantitative survey results, the number of responses for each category was summarized.

Results

We conducted several workshops throughout the semester on socially engaged design principles and software development strategies. In the end, we asked students if they anticipate using the information from the workshops in their future academic or professional careers. Students answered using a 5-point scale (strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, and strongly agree), and the responses were overwhelmingly positive, as shown in Figure 1:

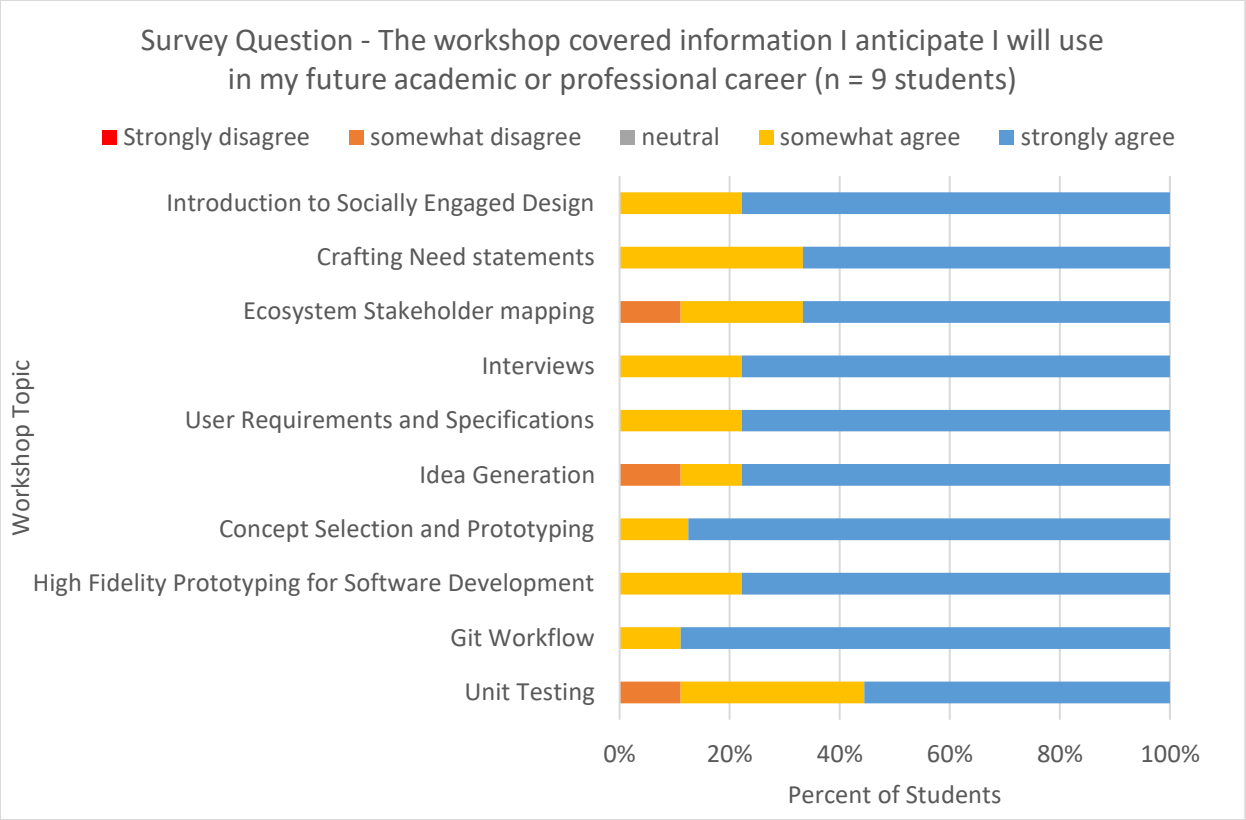

Figure 1. Survey results examining the usefulness of the workshops.

Benefits of the SET content for their projects

We examined reflection data from the exit survey based on what students perceived as the most useful things they have learned from the experience. The summary of the common themes is presented in Table 3.

Table 3. Common themes describing the most useful things they have learned from the experience.

Theme	**Description**
Learning the socially engaged design process	Students emphasized the importance of planning their design process that considers social and cultural factors.
Engaging with stakeholders	Students described the importance of understanding the needs of stakeholders and gathering their feedback in their process.
Generating ideas using recommended practices	Students articulated the importance of spending time to generate ideas using recommended practices such as considering non-obvious and diverse ideas to solve their problems.
Developing prototypes before coding	Students discussed the importance of generating early prototypes to receive feedback before coding their solutions.

Theme 1: Learning the socially engaged design process.
Students articulated the importance of learning about the socially engaged design process that helped them plan out their projects. Students emphasized that they learned to develop a project from beginning to end that considers stakeholder perspectives:

> *"Another useful skill was learning how to create a project. There is so much [more] than just coding a project or making it. There is also the process of planning it, interviewing people, drawing a prototype, etc. I didn't know there were so many important layers to creating a project. All these layers lead to a very successful product. I'm very grateful to have learned this. This is something I feel I will take with me for the rest of my life."*

Theme 2: Engaging with stakeholders
The students emphasized the importance of learning to engage with stakeholders to gather information before developing their technology. Understanding the needs of the stakeholders was crucial for having a successful outcome as they learned that software engineering involved much more than writing code, but it ultimately required solving a problem with stakeholders.

> *"Without a doubt, the most useful thing I have learned from experience is the fact there is so much more to software engineering than writing code. I learned that with any problem we want to solve, we need to take the time to understand the people who are directly and indirectly.*

Similarly, another student emphasized the shift in his mindset about the process of software development and described the importance of taking input from the users to design a product that will ultimately benefit their users.

> *"I always thought about software as engineers making things that they found cool and not really taking much input except from the people who are paying us. Thus, doing so with people who are users and not just the sellers of our app allowed us to design it in a manner that is most inclined to benefit our users- as it should be, especially with an app like ours that seeks to help people in the real world."*

Another student emphasized the importance of learning that projects can fail after launch if they do not consider stakeholder data. Interviewing the target audience and receiving feedback from stakeholders will ensure that their final products are more likely to be successful:

> *"I think the best workshop was the one where it involved interviewing stakeholders…This taught me how important it was to interview your target audience and get massive feedback before implementing anything. Just because it sounds good on paper or in several practices, it does not mean it will be good [in] the long run. That really stood out to me. It also makes sense why a lot of project[s] tend to fail after launch because they didn't do enough interviewing with valuable stakeholders."*

Theme 3: Generating ideas using recommended practices

Students also benefited from learning about recommended practices in ideation that provided guidelines with an emphasis on generating diverse ideas without evaluating them early in the process. Students described the benefits of having structure to ideation:

> *"One of the workshops that helped me the most for the project was the idea generation workshop. I am a workhorse but not much of a critical thinker, so this workshop helped me personally to think harder about ideas that would help society. I like the process that I learned for idea generation and the five principles that help structure and guide idea creation. I like the principle of wild ideas and avoiding having to evaluate each idea on whether it is realistic or not. I also like the design heuristics because it gave me a baseline to structure my ideas around."*

The idea generation workshop emphasized several ideation techniques including brainstorming and Design Heuristics to help students consider non-obvious solutions to their problems. Students described that providing specific strategies to provide scaffolding helped them consider more unique ideas to solve problems:

> *"Idea Generation workshop was exceptionally useful in coming up with unique and 'out-there' ideas. I personally struggle with coming up with fresh ideas, so doing it in an odd sort of way helped me."*

Theme 4: Developing prototypes before writing codes

Students at the exit survey also demonstrated the value of prototyping early in their design before generating their program. Prototyping served as a way to plan out their design and visualize their ideas before writing codes to further develop their ideas:

> *"[It] introduced me to the world of engineering and prototyping and all the stages that come before writing code. These workshops helped especially because I would have never thought to prepare my ideas before starting to write code. Before, I wrote code as I conceived, but now I know I must conceive, visualize, and create a prototype before I start to bring anything to life."*

<u>Perceived challenges of implementing the SET content for their projects</u>

Throughout the semester, students reflected on perceived challenges each week as they implemented content from the workshop to make progress on their projects. The common themes are listed in Table 4:

Table 4. Perceived challenges throughout the semester.

Theme	**Description**
Lack of experience	Students have not learned socially engaged design skills before and expressed concerns about implementing ideas from the workshop effectively.
Connecting with stakeholders	Students had challenges identifying contacts and connecting with stakeholders who could provide meaningful information.
Translating and prioritizing stakeholder data into requirements and specifications	Students found it difficult to translate and prioritize stakeholder data for their projects.

Theme 1: Lack of experience

At the beginning of the semester, students were introduced to the socially engaged design process. During their reflection, students showed concern about implementing aspects of socially engaged design principles as they have not been exposed to a design process that emphasizes consideration of social, and cultural factors:

> *"Speaking for myself, I have only personally approached design from the perspective of functionality and necessity as opposed to utilizing solutions [that] aim to evoke specific feelings through design and experience. This shift in thinking from solely functional design to a more holistic approach that considers the user experience will be difficult, but crucial for us to create a software solution [that] truly stand[s] out. In addition, I think we'll need to educate ourselves on further design principles and methodologies to properly execute our ideas."*

The theme of concerns due to a lack of experience was repeated regularly. After introducing students to the process of engaging with stakeholders through interviews, students articulated that they may face challenges gathering data through interviews due to their lack of experience:

> "*The most significant barrier to the implementation of the interview practices we went over in this workshop will absolutely be my own lack of significant experience conducting formal or casual interviews. As a CS major, I'll admit I've spent more time in front of a screen than in front of colleagues, and as such it will undoubtedly be a small challenge getting over my own individual anxieties surrounding interviewing. This is particularly something I want to work on, as I expect being anxious during interviews would inadvertently cause my interview subject to also become anxious, thus limiting the amount of information I would be able to record."*

Oftentimes, students described that it was their first time implementing socially engaged design principles such as interviewing to gather data and expressed concerns that they may not effectively implement what they have learned from the SET content for their projects.

Theme 2: Connecting with stakeholders.
The project experience required students to identify needs and connect with stakeholders to gain a deeper understanding of their problem contexts. Students needed to research different stakeholders involved in addressing their problems and reach out to them.

> "*A challenge is actually finding those with disabilities to interview… Another challenge could be not having a wide enough pool of different disabilities to interview. I know many of my groupmates do not have enough contacts with physical disabilities.*"

Theme 3: Translating and prioritizing stakeholder data into requirements and specifications.
Students also described the challenges of translating stakeholder data into requirements and specifications along with prioritizing which information would be important for their final design. For example:

> *"A challenge that our team could encounter is possibly finding out which requirements and specifications will actually follow through in our end product."*

When students received a large amount of information from their stakeholders, students described concerns about identifying and prioritizing the most important ones for their project:

> *"As we do interviews with our stakeholders, we may find a plethora of requirements, but it can be difficult identifying the most important requirements to incorporate into our solution(s)."*

Students needed to collect and prioritize data they had gathered from various stakeholders and incorporate their feedback into their design. Due to the large amount of data that they collected from various resources, students faced challenges identifying clear patterns of information that are considered more important than others.

Discussion and Implications
This study aimed to examine the experiences of students using the SET during a semester-long, extracurricular project experience. The findings identified different themes that demonstrated the benefits of incorporating various SET workshops as well as the perceived challenges of using the SET materials for their projects. The findings complement previous studies while providing more insights into supporting students in software development.

Students articulated the benefits of learning the socially engaged design process that guided them in their planning process as well as helping them incorporate social and cultural factors early into their design. Going through a structured process required them to spend time identifying key issues associated with the problem by understanding the needs of their stakeholders. Providing this scaffolding in the socially engaged design process can help them explore and comprehend the problem better instead of prematurely attempting to solve the problem, following recommended practices in design (Crismond & Adams, 2012).

Although students articulated the benefits of the SET content, students described challenges and a lack of confidence in applying socially engaged design principles due to lack of experience.

The literature describes the process of going from a novice to an informed designer through intentional practices (Crismond & Adams, 2012). Having a single learning experience in socially engaged design is unlikely to be sufficient preparation for them. Expanding learning opportunities to practice these socially engaged design skills can be considered by integrating them throughout the curriculum.

Students benefited from learning strategies to understand the needs of stakeholders and gather their feedback in their design process. At the same time, students described the challenges of identifying and working with stakeholders due to limited existing networks. When instructing students in stakeholder engagement, instructors can reduce this barrier by having students work on problems that may not require access to select groups of stakeholders or working to identify stakeholders for students during the planning process of this learning experience.

Students also emphasized the benefits of having structure and being equipped with idea generation strategies. Prior research examining idea generation documented that engineering students adopted more recommended practices after going through the SET content (Lee et al., 2023). Similarly, students in software development articulated the recommended practices in ideation after going through the semester-long project experience, demonstrating their shifts in mindsets.

Students described the benefits of developing prototyping that helped them prepare and visualize their ideas before developing codes. Students created early prototypes that focused on visualizing their potential solutions and communicating key functionalities of their ideas, which ultimately aided in developing their ideas before writing codes. Prototypes can help minimize design errors and a recommended practice encourages using inexpensive prototypes early and efficiently (Kelley & Littman, 2001; Yock et al., 2015). This allows for a greater number of iterations and supports designers in developing a better solution without large amounts of sunk cost (Houde & Hill, 1997). Similarly, students involved in the program used their prototypes to conceptualize their ideas early without investing too much time and energy into writing codes.

The SET content library includes a range of materials that can be delivered as workshops or hybrid learning modules, allowing faculty to integrate different principles of socially engaged engineering into their courses or extracurricular experiences. Instructors can leverage the SET as a stand-alone lesson to emphasize particular skills or use multiple modules to complement their learning objectives. The SET serves as a valuable tool for engineering instructors who may face knowledge or time constraints and may not be able to effectively cover socially engaged design principles alongside traditional engineering content.

Limitations

This study examined students from a single institution in the U.S., and findings from other settings may be different. Additionally, this study was limited by the sample size and diversity of our participants. A more diverse group of participants may have revealed additional benefits and challenges of using the SET materials. The study was designed to gain an in-depth understanding of students' experiences instead of aiming for generalizability of the results (Creswell, 2013). Qualitative studies emphasize the transferability of results, allowing other researchers to make

connections between this study and their contexts (Patton, 2015). The analysis reflected self-reported data and future studies can examine additional data to triangulate the results.

Conclusion

This study described the process of equipping students in software development with socially engaged design skills through a semester-long extracurricular experience. Student reflections were used to explore student experiences as they implemented the lessons from the socially engaged design workshops. Students emphasized the benefits of learning the socially engaged design process that considers social and cultural factors, engaging with stakeholders to understand the needs of stakeholders throughout their development, spending time to generate a large quantity of diverse ideas, and developing prototypes to receive feedback before writing codes. On the other hand, students expressed challenges as they often lacked prior experience in considering social context in their design, faced challenges identifying stakeholders who could provide meaningful information, and found it difficult to translate and sort stakeholder data for their projects. Findings from this study have implications for integrating the SET to support student learning in software development.

Acknowledgments

This project was supported by a technology company and the National Science Foundation, under grant 2013410. The authors would like to acknowledge support from the Center for Socially Engaged Engineering and Design.

References

ABET. (2019). *Criteria for accrediting engineering programs, 2019-2020*. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/

Center for Socially Engaged Design. (n.d.). Center for Socially Engaged Design. Retrieved September 10, 2018, from http://csed.engin.umich.edu/

Creswell, J. W. (2013). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications.

Crismond, D. P., & Adams, R. S. (2012). The Informed Design Teaching and Learning Matrix. *Journal of Engineering Education*, *101*(4), 738–797. https://doi.org/10.1002/j.2168-9830.2012.tb01127.x

Duderstadt, J. (2008). Engineering for a changing world: A roadmap to the future of engineering practice, research, and education. *Ann Arbor, MI: The Millennium Project*. http://milproj.dc.umich.edu/.

Houde, S., & Hill, C. (1997). Chapter 16—What do Prototypes Prototype? In M. G. Helander, T. K. Landauer, & P. V. Prabhu (Eds.), *Handbook of Human-Computer Interaction (Second Edition)* (pp. 367–381). North-Holland. https://doi.org/10.1016/B978-044481862-1.50082-0

Howitt, P., Darzi, A., Yang, G.-Z., Ashrafian, H., Atun, R., Barlow, J., Blakemore, A., Bull, A. M. J., Car, J., Conteh, L., Cooke, G. S., Ford, N., Gregson, S. A. J., Kerr, K., King, D., Kulendran, M., Malkin, R. A., Majeed, A., Matlin, S., … Wilson, E. (2012). Technologies for global health. *The Lancet*, *380*(9840), 507–535. https://doi.org/10.1016/S0140-6736(12)61127-1

Kelley, T., & Littman, J. (2001). *The art of innovation*. Currency.

Kouprie, M., & Visser, F. S. (2009). A framework for empathy in design: Stepping into and out of the user's life. *Journal of Engineering Design*, *20*(5), 437–448. https://doi.org/10.1080/09544820902875033

Lattuca, L., Terenzini, P., Knight, D., & Ro, H. K. (2014). *2020 Vision: Progress in Preparing the Engineer of the Future*. http://deepblue.lib.umich.edu/handle/2027.42/107462

Lee, J. W., Daly, S. R., & Vadakumcherry, V. (2018). Exploring Students' Product Design Concept Generation and Development Practices. *American Society for Engineering Education*.

Lee, J. W., Daly, S. R., Vadakumcherry, V., & Rodriguez, G. (2023). Idea generation, development and selection: A study of mechanical engineering students' natural approaches and the impact of hybrid learning blocks. *Design Science*, *9*, e29. https://doi.org/10.1017/dsj.2023.26

Loweth, R. P., Daly, S. R., Liu, J., & Sienko, K. H. (2020). Assessing Needs in a Cross-Cultural Design Project: Student Perspectives and Challenges. *International Journal of Engineering Education*, *36*(2), 712–731.

McPhate, M. (2015). Discrimination by Airbnb Hosts Is Widespread, Report Says. *The New York Times*. https://www.nytimes.com/2015/12/12/business/discrimination-by-airbnb-hosts-is-widespread-report-says.html

Mosyjowski, E. A., Daly, S. R., & Skerlos, S. J. (2023). Investigating an Asynchronous Model for Incorporating Social Aspects of Engineering Work into Engineering Design Courses. *International Journal of Engineering Education*, *39*(4), 798–810.

National Academy of Engineering. (2015). *Educate to innovate. Factors that influence innovation: Based on input from innovators and stakeholders.* The National Academies Press.

Nieusma, D., & Riley, D. (2010). Designs on development: Engineering, globalization, and social justice. *Journal of Engineering Studies*, *2*(1), 29–59.

Palmer, B., Terenzini, P., McKenna, A. F., Harper, B. J., & Merson, D. (2011). Design in context: Where do the engineers of 2020 learn this skill. *Proceedings of the 118th Annual Conference of the American Society for Engineering Education*.

Patton, M. (2015). *Qualitative Research & Evaluation Methods: Integrating Theory and Practice* (4th ed.). SAGE Publications.

Strehl, E., Loweth, R., & Daly, S. (2022). Evaluation of a Hybrid Learning Block Model for Engineering Design Interview Skill Building. *Advances in Engineering Education*, *10*(4). https://doi.org/10.18260/3-1-1153-36037

Wood, A. E., & Mattson, C. A. (2016). Design for the Developing World: Common Pitfalls and How to Avoid Them. *Journal of Mechanical Design*, *138*(3). https://doi.org/10.1115/1.4032195

Yock, P., Zenios, S., Makower, J., Brinton, T., Kumar, U., Watkins, J., Denend, L., Kummel, T., & Kurihara, C. (2015). *Biodesign: The process of innovating medical technologies* (2nd ed.). Cambridge University Press.