ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #37957

Social Justice Curriculum in Thermal Systems and Mechanical Systems Design: What Motivates Students to Engage?

Jennifer Peuker, California Polytechnic State University, San Luis Obispo

Erin Kay Moss, California Polytechnic State University, San Luis Obispo

Jaxon Silva, California Polytechnic State University, San Luis Obispo

Emily Wannenmacher, California Polytechnic State University, San Luis Obispo

Lauren Anne Cooper, California Polytechnic State University, San Luis Obispo

Social Justice Curriculum in Thermal Systems and Mechanical Systems Design: What Motivates Students to Engage?

Introduction

The purpose of this paper is to present results from ongoing work related to integrating social justice content into technical courses in mechanical engineering. Understanding of social justice issues and the ability to engage in sociotechnical thinking are vital aspects of engineers' skill sets in the 21st century, but many engineering programs present content in ways that obscure or minimize these critical links. It is well-understood that student motivation is critical for engagement and learning to take place in the classroom. In our case, achieving participation and engagement in discussions and projects related to social justice requires motivated action on the part of both students and faculty. Without understanding the specific elements that support or inhibit student motivation to engage with social justice content within an engineering course, educators may feel confused about why certain students embrace this type of curricular intervention while other students engage minimally or outright reject it.

There has been extensive research on the relationship between learning and motivation of students in general and the conclusions related to teaching and learning can and should be applied to teaching social justice topics in the engineering classroom. According to Ken Bain in *What the Best College Teachers Do*, "People learn best when they ask an important question they care about answering or adopt a goal they want to reach…If we are not seeking an answer to anything, we pay little attention to random information." [1] Therefore if we are going to motivate students to want to learn about and engage in sociotechnical thinking in their engineering classes, then we must frame it around issues that students already care about and/or questions they have. We must present students with interesting problems and ask them to engage with the topics in a personal way–asking their own questions about the implications of technologies and applying the ideas/questions to their life. Finally, "we have to give the students opportunities to respond in authentic ways" such as in discussions, and reflections rather than exams. [2]

Much of the curriculum for engineering education is singularly focused on technical fundamentals and the design of systems. While these methods of study are undoubtedly useful to determine whether or not a system "will work" or how it will impact a company's bottom line, this focus on technical thought generates a blind spot in which students do not have the tools to investigate the broader impacts of the systems they design have on the environment or society. While scholars in the field of Science and Technology Studies have developed many case studies on the effects of technologies on the environment and society, [3-6] engineering education seems to have not incorporated these case studies into its practices of what is considered "good design," instead remaining steadfastly committed to a purely technical focus in engineering education, something

that has been shown to reduce students' willingness to think critically about their designs and have devaluate the importance of their ethical responsibilities as engineers. [7]

There are multiple and varying definitions of social justice; for our purposes, we chose to understand social justice as something that stresses the importance of equity and accessibility in resources, and the protection of human rights. This description of social justice carries a mandate to analyze and acknowledge the structural and social inequalities present in society, and work to empower those most marginalized by these systems of inequality. The work to fulfill the mandate may come in many forms, from actively changing institutions–whether that be government, academic, or economic–policies, and systems that actively cause violence for marginalized groups through inequitable practices and lack of access to resources. [8,9] In terms of engineering design, this may require a new reconceptualization of problems from perspectives typically not associated with engineering thought, the utilization of technical and scientific knowledge for creating more equitable ways of life, [10] and to confront those who promote the design choices and decisions that replicate the systems of domination existent in modern society. [11]

We hope that through illuminating the social justice issues surrounding engineering practices in core engineering courses, we can (1) inspire students to investigate and acquire a much more holistic understanding of engineering practice that is intimately bound with issues of energy policy, sustainability, global systems of extraction, bias in design, etc. (2) move past the technical/social dualism currently present in engineering education to empower students to learn about and participate in social justice issues and discussions, and (3) give students the tools and skills to learn how they can incorporate social justice work in ways that support their professional development and career plans. This paper will summarize and synthesize our key findings across the three qualitative data strands. By shedding light on the factors that influence student motivation to engage with social justice content in engineering courses, we can help other faculty who are working toward related curricular transformations at their institutions.

Methods

In a mechanical engineering program at a large, primarily White public institution on the west coast—Cal Poly, San Luis Obispo—students in a senior-level thermal systems design course were assigned social-justice themed projects on a variety of topics related to energy during the AY 20/21 in two terms—Fall 2020 and Spring 2021. For Fall 2020, the students did four projects (project 3 had two distinct parts), and for each project they had the choice of topic. A comprehensive list and description of the topics can be found in [12]. Projects 1 and 3 were adapted from Riley [13] and had 2-3 options for each project, while the second project had more options and were topics related to current issues and energy concerns, such as clean water access. In Spring 2021, the students did one project and had the choice of three topics: Solar Panels, Building De-

Carbonization, or Booster/Peaker Power Plants. The topic options and reduction to one project for Spring 2021 was based on feedback and experience in Fall 2020.

In addition to giving students the choice of project topic, for each project the students attended a discussion session with classmates who chose the same topic. After the live discussion, all students participated in an asynchronous online discussion in which they had to first describe why they chose their topic, what they learned in the live discussion and what questions they still had. The requirements for the online discussion included responding to at least two classmates. Finally, the report for each project followed a modular format that engages students in a four-step iterative process: Engage, Analyze, Reflect, and Change, as laid out by Riley. [12,13] The Engage and Analyze sections challenged students to do research on their topic to be able to not only understand the technology, but also investigate social/racial/economic discrepancies in who uses the technology or has access to it. The Reflect section asked students to not only reflect on what they learned during their research on the topic, but also to reflect on whether their viewpoints had changed and if so how. The Change section challenged students to think about what actions they could take, the engineering profession could take, and/or other solutions to the problems.

Using a thematic analysis, we used inductive open coding and then axial coding to analyze the project reports and reflections from both Fall 2020 and Spring 2021. The open coding was conducted through the utilization of Dedoose software in analysis of student reports, and our axial coding was greatly enhanced through the visualization tools offered by the Coggle web application. The thematic codes we found through our analysis covered a wide range of topics related to social justice and sociotechnical systems and are listed in table A.1 listed in the appendix.

In addition, to further explore the factors that influence student motivation, we conducted focus groups in Summer 2021 with students from the thermal systems design courses, as well as students in a junior-level mechanical systems design course. Focus groups participants volunteered and were compensated with a gift card for their time. All focus groups/interviews took place over zoom with a minimum of two student-researcher proctors. One proctor read the pre-determined focus group questions while the other managed the slideshow, asked probing questions, and intervened (if necessary) to ensure participant and proctor safety. Participants were encouraged to build off each other, allowing for an interactive critical thinking process. All transcripts were anonymized, and any identifiable information removed for post processing.

The Thermal System Design focus groups explored students' opinions and experiences with the social justice themed projects they completed in the Thermal System Design course (ME 420) and were recruited from those who took the class with Dr. Mott in Fall 2020 or Spring 2021. One focus group was conducted for students who took the course in Fall of 2020, and another focus group was conducted for students who took the course in Spring of 2021. The proctors asked the following five main questions to each group of students with follow-up questions as needed.

1. What does social justice mean to you? Why is engineering important to you, and why is social justice important to you as an engineer?
2. Do social justice topics belong in the engineering curriculum? What are some reasons why students do not want to explore social justice topics in engineering classes?
3. Do you think these projects were effective in exploring the connection between social justice and engineering? In what ways were the projects not effective? What other ideas do you have for future ME 420 classes?
4. How did the projects within the class change or grow your perspectives on social justice topics including, but not limited to: racism, sexism, ableism, and inequality writ large?
5. In our analysis, we found that students tended to defer decision-making of engineering projects to other groups and/or individuals. Could you explain why you think this occurred?

For the Mechanical Systems Design course, data collection methods consisted of five interviews and one focus group. The original goal was to facilitate mainly multiple-student focus groups, but participant availability made this difficult. All participants volunteered by filling out a set of google forms which were emailed to the Dr. Coper's previous two quarters' students. The focus groups and interviews were led entirely by student researchers (two/three research proctors present for each meeting) and started by asking student participants to describe the term sociotechnical. After hearing participant responses, proctors provided a definition of sociotechnical, as the "interplay between relevant social and technical factors in the problem to be solved", to be referred to throughout the session. Next, students were asked to identify a real-world engineering problem that could be classified as sociotechnical, and to identify any engineering coursework or classroom experience that has addressed this topic. After the students were introduced to the concept of sociotechnical issues, an example was introduced to add context and inspire critical thinking for the following questions. The construction of the Thirty Meter Telescope (TMT) on Mauna Kea, a complex machine with gears, shafts, bearing and fasteners (all components covered in Mechanical Systems Design), was described through a sociotechnical lens: exploring the conflict between the scientific community and the Native Hawaiians surrounding the location choice (a sacred Native cultural site with the ideal conditions for astronomy data collection). After briefly exploring this case study, students were asked five remaining questions regarding teaching social considerations alongside technical content. Finally, they were asked to list potential positives and negatives for including this content in Mechanical Systems Design, to state whether or not they believed it "belonged", and to identify any personal emotional responses this discussion provoked.

Results and Discussion

For Fall 2020, 40 students agree to participate in the research and in spring 2021, 13 students agreed to participate by allowing us to analyze their course work. No demographic data on the students was collected. As stated in the methods section, the changes for the second term of

assigning these projects in the thermal systems design class were based on feedback from the Fall 2020 students, both as formal course feedback and informal feedback that came from both talking to the students and the instructor's professional judgment for making course modifications for the purpose of increasing the motivation of students to want to engage in the project. In choosing the topics for the project for Spring 2021, the selection was based on which topics from Project 2 in Fall 2020 were most popular, were most closely related to current issues in the world and could be easily relatable by the students.

In addition, student comments from the fall term indicated that students had expected to have a design project. It seemed too that the four projects in one term were too many such that the topics could be adequately explored for each project, and the students were tired at the end of the term. As this was likely the first time many of these students had encountered these topics in an engineering class, it is possible that the project over did it for some of the students. Therefore, for the spring term, the student did a design-based project and ended the term doing the social-justice themed project. From the perspective of the instructor, this seemed to be a good balance for the course workload, in addition to having fewer options for the project (compared to seven for Project 2 in the fall), allowed for 8-10 people per live discussion session, which was a good number for getting the conversation going and allowing time for everyone to talk. Since the thermal systems design course is senior level, most of the students have had internships and many in the energy/power industry. It was fortunate that students in the spring term had internships in the solar or power plant industry and could offer unique perspectives to the other students based on their experiences. This additional insight not only motivated those students to learn more in doing the project, but also their enthusiasm was contagious.

The initial inductive open coding of the project reports from the thermal system design course resulted in 18 distinct codes that were then combined into five categories: (1) Identification of Social Justice Problems, (2) Personal Experience, (3) Make connections to Engineering (4) Challenges to Understanding and (5) Change/Future. The full list of codes and their working definitions can be found in the Appendix. The five categories and their connections to each other through the different thematic codes can be visualized in Figure 1. A key relationship is the student's identity in relation to engineering, and their ability to make connections to engineering and identifying social justice problems. This relationship is shown in Figure 2, where each bubble represents a team, and the size of the bubble relates to their identity in relation to engineering, as measured by the number of times they referenced being an engineer in their writing. Being able to identify social justice inequalities helped students be able to make the connection between engineering and social justice. The informal (yet still instructor moderated) online discussion was the part of the assignment that helped students the most to see the connections to engineering and identify inequalities. To get students to engage in these topics then we should facilitate these informal learning opportunities to explore their personal reasons for choosing a topic and responding to colleagues on their thoughts.

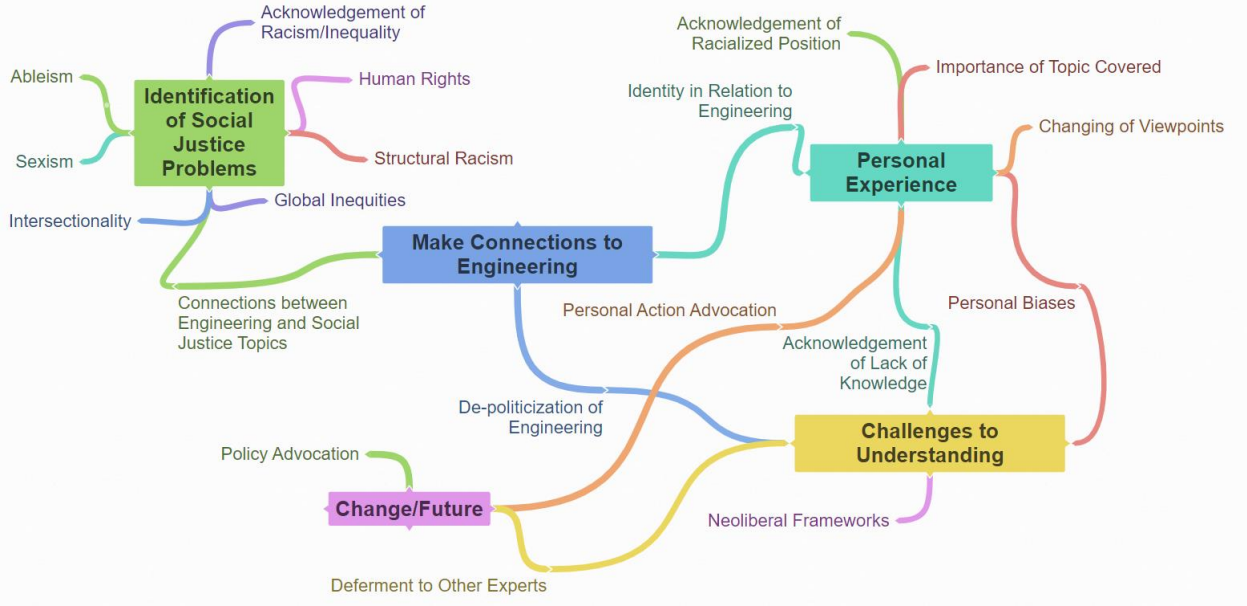

Figure 1. Visualization of the five thematic categories found from project reports and their relationship to each other through thematic codes.

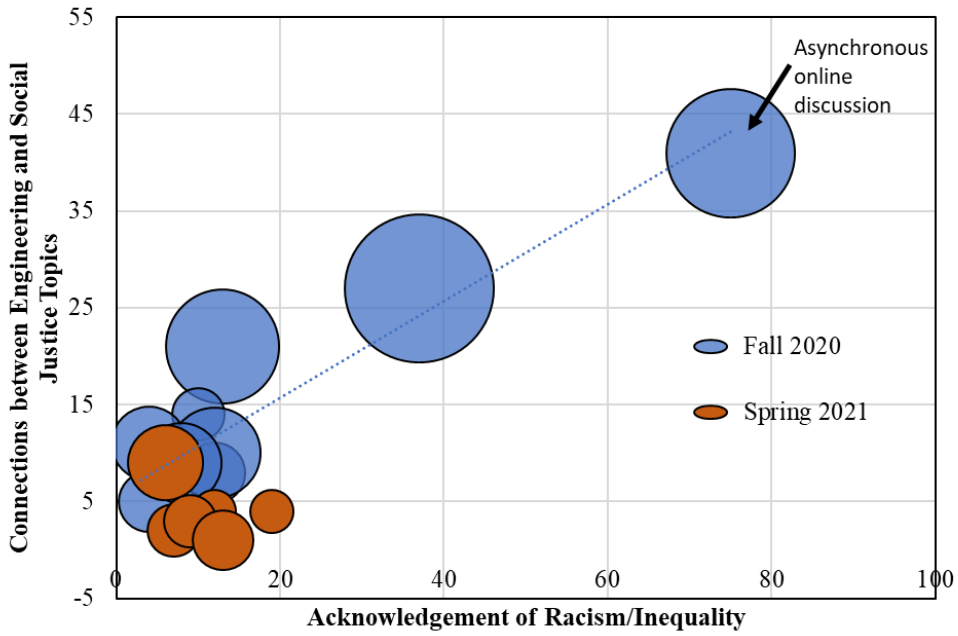

Figure 2. The relationship between acknowledging racism or inequality and being able to see the connections between engineering and social justice topics. The size of bubble is identity in relation to engineering, and each bubble represents a team, except as noted

The Fall 2020 cohort had more opportunities to explore social justice topics, so the following two plots are for Fall 2020 only. In Figure 3, we see that if students can identify their role as an engineer in social justice issues, then they feel more likely to advocate personal action. While Figure 4

shows that students are more likely to advocate for policy changes while also deferring to other experts. It is interesting because these projects pushed students out of the technological knowledge comfort zone, where when thinking about solutions it can be easier to defer to policy action and other experts. Recognizing the bigger picture is positive but can also help students see their role in all of it by how we formulate the projects, topics and discussions to help them make the connections between themselves as engineers and the issues/solutions.

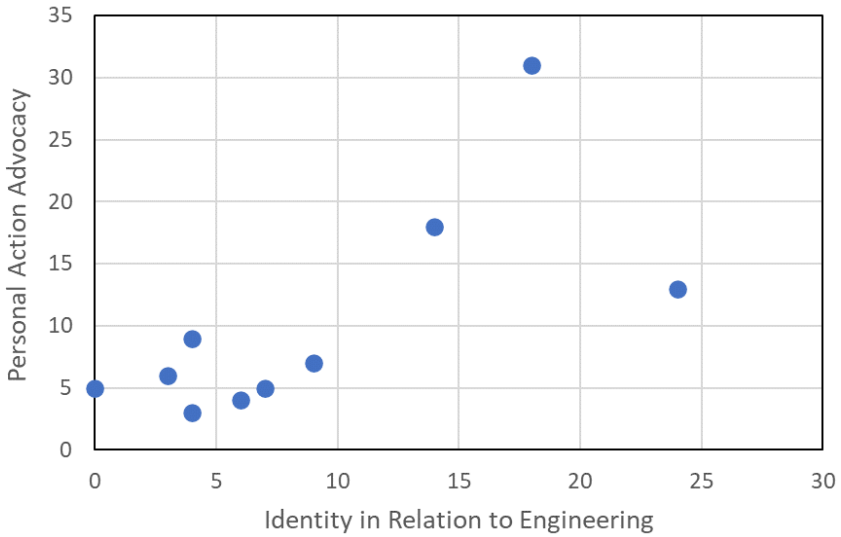

Figure 3. Relationship between identity in engineering and personal action for Fall 2020.

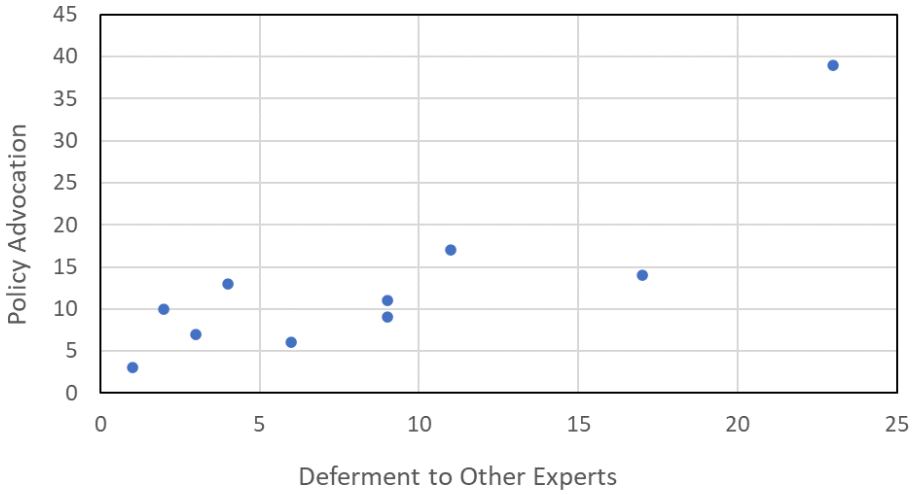

Figure 4. Relationship between students deferring to experts and policy advocacy.

Since the two terms had different numbers of teams and project reports, the frequency of the codes for each of the five categories were normalized to the largest frequency for each term. The results by project are presented in Figure 5. Every project, to some extent, was successful in helping students identify social justice problems, and make connections to engineering. The projects with

the highest counts include the solar panels topic (Spring 2021 Topic C) and Fall 2020 Projects 1 and 2. While all projects helped students make connections to social justice topics, providing different topic options also helped them invest in an area they care about and are interested in exploring deeper. Question 3 in the Thermal System Design focus groups further explored how effective these projects were.

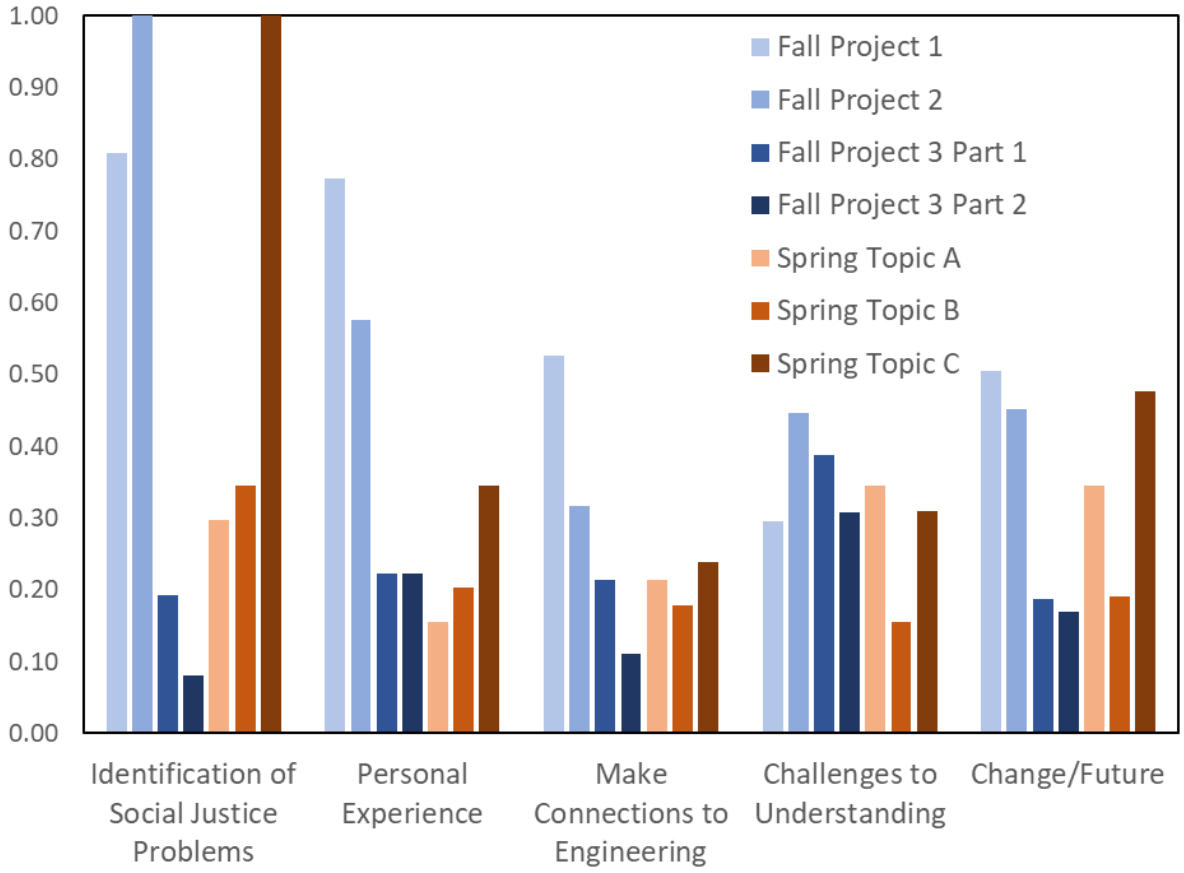

Figure 5. Normalized Code Frequency–each term was normalized to the highest number of coded comments. The five categories were determined from the 18 original codes based on the student reports.

The Thermal System Design focus group provided insight into students' experiences with the social justice themed projects in their engineering coursework. Six students total (two from Ffall 2020 and 4 from spring 2021) participated in the focus groups, no demographic information was collected on the students. First, we found that social justice is important to engineering students because engineers are responsible for designing solutions that are available, accessible, and usable by all types of people. While all students felt that social justice topics belong in the engineering curriculum, Question 2 allowed us to understand some barriers to engaging in these projects. The participants suggested that not all engineering students are readily willing to complete assignments that aren't technical with calculations or design work. Therefore, they recommended that there

needs to be a perfect integration of social justice topics in the engineering curriculum so that none of the current instruction is sacrificed. To improve the projects, students suggested that they should include calculations in addition to research. Students also need to feel that the subject matter is worth their time since the engineering curriculum is heavy as it is. Explaining to students why social justice topics in engineering is important for this reason. In addition, students might feel uncomfortable discussing their opinions on different conflict matters with their peers. Providing a non-judgmental setting for students helps set the tone for an open discussion and allows all to participate.

Based on the responses to Question 3, some motivating factors to engage in the projects included providing different project topics, discussing their findings with peers, and gaining new perspectives and knowledge not covered in other classes. By selecting their project topic, students were able to investigate social justice problems in an area they care about. Students expressed that the projects opened their eyes to factors that they never had thought about or considered as it relates to their roles as engineers. Overall, personal outcomes varied, but most students thought that the projects they completed were an effective means of incorporating social justice in engineering coursework.

The Mechanical Systems Design focus groups and interviews gave valuable insight into student attitudes surrounding socio-technical content and whether these topics belong in a course previously deemed "purely technical". Six sessions were held, each with 2-3 student participants, for a total of 7 participants. No demographic information was gathered on the student participant.

Once group consensus was formed around the definition of sociotechnical ("interplay between relevant social and technical factors in the problem to be solved"), participants generally saw value in exploring these topics within an engineering context. Participants who had experience in industry, whether through internships or other means, valued sociotechnical thinking highly: viewing it as an integral part of the engineering profession. The two following quotes from students highlight that students do indeed recognize that the two topics (technical and social factors) are indeed important:

> "I think **it would be harder to find an example of an engineering problem in the world that isn't socio-technical** at first glance. I think how we're taught to think in the ME program is kind of cut and dry analysis. **We're doing technical analysis and I think a lot of problems are more than just that**."

> **"[Y]ou never design in a bubble. There's always other things around you that you have to consider."**

Even though we know these topics are interrelated and students are interested in them, there remains a hesitancy to incorporate social justice topics in core engineering classes. Hesitancy around implementing socio-technical content in Mechanical Systems Design stemmed mainly from three areas: creating overwhelming course loads, losing valuable technical material, and failing to create a safe environment for these discussions. Students who had experience with social justice content varied in their appreciation for its inclusion. Some students found the material "forced" or "divisive" while others found it valuable for widening worldviews. Many students suggested adding a separate required course to the Mechanical Engineering curriculum which would focus specifically on these topics: a mechanical engineering ethics class similar to requirements within other engineering majors.

> "You don't really want a hostile environment in your class when you're supposed to be open to learning. So, you really don't want to divide the class off the bat, especially in a design class where collaboration is key."

> "If it's done properly, it's fascinating, and it widens people's visions so much, but done improperly it just shuts people off."

Overall, participants saw value in exploring these topics within the Mechanical Engineering curriculum. There was general agreement that this kind of content would contribute to widening world views, creating a more inclusive learning/working environment, and preparing students for real-world engineering.

> "[I]f someone, from that cultural community were to be taking those classes, they might feel like they matter or that they, **their issues, their cultural and their personal issues**, those issues that form a part of their **identity, just by being considered, I feel like that really makes them feel like they belong**. "

Conclusions

Our key findings show that projects in the thermal systems design course helped students recognize racism/inequality and make connections between engineering and social justice topics, and that many students recognize their lack of knowledge and personal biases, allowing them to change their viewpoint. There is a direct relationship between students acknowledging racism and inequalities and being able to make connections between engineering and social justice issues. In addition, if a project helped students identify their role as an engineer in social justice issues, they feel more likely to advocate personal action.

Students from both thermal systems design and mechanical design courses shared that while they may be personally interested in topics of social justice, they worry about the way inclusion of

social justice curriculum might "take away" from important technical topics, and that the addition of these extra assignments can create an even more burdensome workload. Hence, there may be a mismatch between students' intrinsic motivation to engage in learning about social justice and the extrinsic factors that motivate students to disengage with social justice. By shedding light on what influences students' motivation, we can help other faculty who are working toward related curricular transformations at their institutions.

As we continue this work, we offer a few recommendations for other engineering faculty who are interested in engaging in the work of social justice integration and sociotechnical thinking. In particular, we need to create a safe environment where students feel comfortable bringing their personal experiences and ideas without judgment. A safe environment is especially important for underrepresented students who may have personal stories related to inequalities they or their families have experienced. Valuing these and other personal experiences is important to help students make connections between the technical and social justice aspects. Second, give students options for their project topic and create the assignment in such a way that they can make a personal connection. We know that students are more motivated to learn if they care about the topic and have a personal interest or see how it applies to their future career. Leverage the students who have already had industry experience and can share why it's important to the engineering profession. Third, show students where the social justice topic fits into the larger picture of the course material. Integrate the learning of technical skills within the context of social justice issues and be transparent that technical content is not cut to "fit it all". Lastly, don't give up. Initially, instructors of both courses received negative feedback from students, but as the focus groups indicated, the students believe these topics are important and should be in the engineering curriculum. The first-time students are presented with a course or assignment meant to break the current technical/social dualism, there will be pushback from both students and other faculty until they too understand its interconnectedness and importance of inclusion in all engineering courses.

References

[1] K. Bain, *What the Best College Teachers Do*. Cambridge, MA, Harvard University Press, 2012

[2] J. Lang, *Cheating Lessons: Learning from Academic Dishonesty*. Cambridge, MA, Harvard University Press, 2013

[3] L. Winner, *The Whale and The Reactor: A Search for Limits in an Age of High Technology*. Chicago, IL: University of Chicago Press, 1986.

[4] H. Collins and T. Pinch, “The science of the lambs: Chernobyl and the Cumbrian sheep farmers,” in *The Golem at Large: What You Should Know about Technology*, Cambridge: Cambridge University Press, 2002, pp. 113–125.

[5] S. Turkle, *Alone Together: Why We Expect More from Technology and Less from Each Other*. New York: Basic Books, 2011.

[6] B. Ruh. *Race After Technology: Abolitionist Tools for the New Jim Code*. Cambridge: Polity, 2019. Print.

[7] E. Cech, “Understanding Engineering Education Culture”, presentation to Cal Poly, San Luis Obispo Engineering Faculty, Sept 8, 2020

[8] D. Riley, *Engineering and Social Justice*, Morgan & Claypool, 2008.

[9] Leydens and J. Lucena, "Engineering Justice: Transforming Engineering Education and Practice, IEEE Press, 2018.

[10] W. E. B Du Bois. *Black Reconstruction in America: [1860-1880]*. New York, NY: The Free Press, 1998.

[11] S. Torres-Harding, B. Siers, and B. Olson, “Development and Psychometric Evaluation of the Social Justice Scale (SJS),” *American Journal of Community Psychology*, vol 50, pp. 77-88, 2012.

[12] Reference will be included in final paper for anonymity of authors during review

[13] D. Riley, *Engineering Thermodynamics and 21st Century Energy Problems: A Textbook Companion for Student Engagement*, Morgan & Claypool, 2012.

Appendix

Table A.1. The list of codes that were determined from the thermal system design course project reports and their working definition.

Category	Code	Code Definition
Personal Experience	Acknowledgement of Lack of Knowledge	Students make mention of how they are not equipped to comprehensively make sense of topics relating to social justice. Students feel like they are unable to make the best decision due to how little they feel they know
	Importance of Topic Covered	Students make mention about how the topic covered is worthy of being viewed as pertinent
	Changing of Viewpoints	Students reflect on how their viewpoint has changed through the project
	Identity in Relation to Engineering	Students reflect on their own identities and how they relate to the issues at hand/their position within the engineering culture
Make Connections to Engineering	Connections between Engineering and Social Justice Topics	Students relate how engineering projects can lead to racialized/patriarchal/ableist/intersectional outcomes. Bonus points if they make reference to sociotechnical/STS stuff
	De-politicization of Engineering	Student excerpts depoliticize the problems at hand and how those problems directly relate to engineering design work, may be done through a direct focus on the technical aspects of a project, a lack of mention of the issues at hand, or hand-waving

	Personal Action Advocacy	Students advocate to address the problem being discussed through personal actions either on their end or for people as a whole
Challenges to Understanding	Personal Biases	Student excerpts are reflective of the personal biases that students carry, pulling them either towards or from social justice topics
	Neoliberal Frameworks	Student excerpts are reflective of neoliberal ideologies, prioritizing cost/efficiency and market-based reforms over more collectivist or even governmental approaches to solving problems.
Change, Future	Deferment to Other Experts	Students define solutions to the problems at hand to be taken over and solved by other experts/policymakers/marginalized groups
	Policy Advocacy	Students advocate for change on the behalf of governmental policy and laws to address the problems discussed
Identification of Social Justice Problems	Acknowledgement of Racism/Inequality	Students actively acknowledge racism/inequality that exists in the world
	Sexism	Student excerpts demonstrate the patriarchal dimensions of the problems being discussed
	Structural Racism	Student excerpts demonstrate how the problem being discussed continues to persist through the problem being baked into the structures of society as a whole

	Intersectionality	Students illustrate the intersectional connections of the problems discussed
	Global Inequities	Student excerpts demonstrate the inequalities present between the wealthy nations of the Global North and the poorer nations of the Global South
	Human Rights	Students argue that certain problems and issues constitute a violation of human rights
	Ableism	Student excerpts illustrate the limitations engineering solutions have for people with disabilities.