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The effects of a humanities-based engineering course on engineering students' sociotechnical thinking

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Abstract

Context

As the world becomes connected and globalized, engineering problems become more complex and multi-dimensional. To solve these problems, engineers require *sociotechnical thinking*, which involves addressing both the technical and contextual aspects of a problem and understanding the interconnections between these considerations. However, engineering programs traditionally emphasize technical thinking, resulting in a lack of sociotechnical thinking during problem-solving.

Purpose or Goal

Humanities-informed engineering education is one pedagogical approach that has shown promise in supporting engineering students' development of sociotechnical thinking skills. Our study explored how enrollment in a one-semester humanities-informed engineering course is related to the development of sociotechnical thinking.

Methods

We administered the Energy Conversion Playground (ECP), a scenario-based assessment of sociotechnical thinking, to three groups at the start and end of the semester: students in the humanities-informed engineering course, other students from engineering majors, and students from humanities majors. Students' performance on each dimension of the ECP (Technology, People, and Broader Context) was compared using a 3x2 mixed ANOVA design.

Outcomes

Our results reveal that students enrolled in the course were more likely to discuss social considerations compared to the two groups not enrolled in the course. Students in the course also improved over the semester in their discussion of social and contextual considerations while the other two groups did not.

Conclusions

The results of the study indicate that interdisciplinary training in humanities and engineering can help engineering students engage in sociotechnical thinking during problem-solving. Moreover, the results for the engineering control group reiterate previous findings that there may be a lack of emphasis on social and contextual aspects in traditional engineering education. Therefore, future research should focus on development of pedagogical frameworks and assessments on sociotechnical thinking.

Keywords*—Sociotechnical thinking, scenario-based assessment, interdisciplinary engineering education.*

I. INTRODUCTION

Problems that engineering students are trained to solve in classrooms are well-defined and closed-ended (Jonassen et al., 2006), and often decontextualized from contextual influences (McGowan & Bell, 2020). In practice, however, problems that engineers encounter are complex, ill-structured, and situated in social contexts, and thus sociotechnical by nature (Leydens & Lucena, 2018). Leydens & Lucena (2018) suggest that the disconnect between classroom and workplace problems is a consequence of technical-social dualism (Faulkner, 2000, 2007) where engineering students are taught to prioritize technical aspects and minimize contextual aspects during problem-solving (Swartz et al., 2019). In the real world however, engineering problems involve a complex interplay between technical and contextual aspects (Kaur & Craven, 2022; Leydens et al., 2018; McGowan & Bell, 2020; Trevelyan, 2014b, 2014a). For instance, engineers are tasked to handle sociotechnical problems such as provide access to clean water, ensure privacy and cybersecurity of people, improve urban infrastructure, make energy sustainable, accessible, and economical, etc. To tackle these sociotechnical problems, engineering students and practitioners require sociotechnical thinking, which can be conceptualized as the ability to address both technical and contextual dimensions of a problem (Mazzurco & Daniel, 2020) and the ability to understand the interconnections between these dimensions (Davis et al., 2021). However, the development of sociotechnical thinking has not historically been emphasized in engineering education.

Humanities-informed engineering education is one approach that has shown promise for developing engineering students' sociotechnical thinking ability (Davis et al., 2021). Humanities-informed engineering course involves teaching students to approach engineering problems through the lens of both engineering and humanities disciplines. It is an interdisciplinary course that uses sociotechnical case studies to develop students ability to consider contextual aspects and broader considerations associated with engineering problems (Davis et al., 2021).

The purpose of the current study was to investigate whether a humanities-based engineering course can develop

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sociotechnical thinking abilities in engineering students as assessed using a scenario-based assessment (Mazzurco et al., 2014; Mazzurco & Daniel, 2020) and to compare the ability of the students in the class to that of other groups of students. We addressed the following research questions (RQ):

1. How do the scores on a scenario-based assessment of sociotechnical thinking compare between students enrolled in a humanities-informed engineering course and control groups of engineering and humanities students?
2. How do the scores on a scenario-based assessment of sociotechnical thinking change from pretest to posttest for the students in the course group and control groups?

Our study responds to ongoing calls for equipping students with sociotechnical thinking skills (Cech, 2013; Leydens et al., 2018; Mazzurco & Daniel, 2020; Swartz et al., 2019; Trevelyan, 2014b). Our findings show that interdisciplinary approaches like humanities-informed engineering may provide opportunities for developing required sociotechnical thinking skills. Further, we reiterate previous findings by showing that engineering students do not often prioritize contextual considerations while solving problems. Finally, we urge educators to develop frameworks and assessment methods that help foster and measure the sociotechnical abilities of engineering students. These targeted efforts will enable universities to prepare engineers capable of addressing complex sociotechnical problems.

II. Literature Review

The problems that engineers face today are complex and consist of various technical and contextual aspects that are interconnected with each other (Kaur & Craven, 2022; Leydens et al., 2018; McGowan & Bell, 2020; Trevelyan, 2014b, 2014a). As a result, engineering problems and solutions exist within a complex sociotechnical space (Adams et al., 2011) indicating that these problems cannot be addressed solely by consideration of technical factors (Leydens & Lucena, 2018). In addition to the technical aspects, prior research on engineering practice shows that engineers are required to consider contextual factors such as stakeholder's needs, economic, political, legal, and environmental aspects of engineering problems (Bucciarelli, 1994; Cross, 2021, 2023; Jonassen et al., 2006; Petroski, 2011) during problem-solving. Therefore, engineers will be better prepared to address problems when they understand both the technical and contextual aspects and their interdependencies (Currie & Galliers, 1999; Davis et al., 2021; Grohs et al., 2018).

Despite engineering problems being sociotechnical in nature, research has shown that a culture of disengagement exists in engineering education that prepares students to prioritize technical aspects over contextual aspects during problem-solving and considers societal concerns tangential to engineering practice (Bardzell & Bardzell, 2013; Cech, 2014; Pawley, 2009; Riley, 2008; Stevens et al., 2014). For instance, Cech (2014) found that students' understanding of the societal consequences of technology solutions declined over the course of their engineering education. This indicates that as students' progress from the first year to the final year of engineering, their consideration of contextual factors like public welfare decreases. Furthermore, as students engage in solving linear, well-defined (Jonassen et al., 2006), and often decontextualized (Erickson et al., 2020; McGowan & Bell, 2020) problems over the course of their engineering education, they tend to discount contextual factors during problem-solving (Stevens et al., 2014). To prepare engineers for addressing sociotechnical problems, engineering education must be centered around teaching skills that encourage learners to value contextual aspects during problem-solving.

Sociotechnical thinking is a skill that enables engineers to understand the complex interconnections between the technical and contextual factors of a problem (Hoople & Choi-Fitzpatrick, 2020). Furthermore, with sociotechnical thinking skills, engineering students can discern how and why technical factors are co-dependent on contextual factors during problem-solving (Swartz et al., 2019), embrace the sociotechnical complexities of a problem (Cech, 2013), and think about how their decision making may impact the society as a whole (McGowan & Bell, 2020). Therefore, it is important to support the development of sociotechnical thinking skills in engineering education.

Research has explored a variety of approaches to develop students' sociotechnical thinking skills. For example, Reynante (2022) investigated how sociotechnical thinking skills of engineering students can be developed by exposing them to a two-course community-engaged engineering program. They found that students enrolled in the program shifted their emphasis from being solely focused on technical aspects to accounting for relevant contextual factors along with technical factors while solving engineering problems. Prior research by Frank (2010) suggests that multidisciplinary educational experiences may also encourage engineers to consider contextual aspects while solving problems. Additionally, Bucciarelli & Drew (2015) proposed a Liberal Studies in Engineering degree to expose students to social complexities and implications of their work through a humanities perspective. Similarly, other studies have shown that multidisciplinary education can help students learn to solve complex engineering problems (Bornasal et al., 2018; Jesiek et al., 2017; Stevens et al., 2014).

For our study, we chose to focus on the humanities which is known to develop professionals' abilities needed to solve socially contextualized problems (Benneworth, 2015). Further, a humanities based perspective improves ability to consider unintended consequences of engineering on the society (Fila et al., 2014) and prepare engineers to keep society central to their problem solving (Hynes & Swenson, 2013). Therefore, we developed a one-credit humanities-informed engineering course. Our objective through this course was to integrate

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engineering and the humanities and, thus, examine the integration of contextual and technical aspects during engineering problem-solving. We exposed students enrolled in the course to engineering case studies that had integrated technical and contextual aspects. Students engaged with the case studies by participating in activities like role-playing, discussions, reflections, in-class readings, and brainstorming in groups. Through these activities, students discussed various approaches to analyzing and solving engineering problems from an integrated contextual and technical perspective. For more information on the course, please refer to Davis et al., (2021).

III. Methods

To address our research questions, we used quantitative research methods. We implemented a scenario-based assessment in a pre/posttest study design at a large midwestern university in the USA.

TABLE I
Sociotechnical Thinking Abilities (dependent variables) assessed by the ECP scenario
(revised by Joshi et al., 2023; developed by Mazzurco & Daniel, 2020).

Dimensions	Definitions and Key Characteristics
Technology	Considerations focused on four technical categories: • *Inputs or constraints to the technology:* Power requirements, time of operation, cost, materials, safety, climate, people as a source of energy, etc. • *Functionality:* Efficiency, feasibility, ease of operation, maximum power generated, friction, storage of energy, functioning of components, alternative techs to meet the same goals, ability to generate the needed energy output, and so forth. • *Long-term technological considerations:* Maintenance, repairs, spare parts, upgrades, etc. • *Additional considerations:* Durability, Focus on system safety/equipment safety; people as part of the larger system; funding, budget, cost of maintenance and operation, etc.
People	Considerations focused on stakeholders' needs, desires, expertise, and degree of participation in the design process (e.g., listening to the community, hearing their voices, collaborating with them in the design process). *Additional considerations*: Focus on the safety of people; the willingness of people participation, and the influence of people on the playground system
Broader Context	Considerations focused on four contextual categories: • *Local norms*: Social norms, culture, gender/ethnic/power dynamics, religious views, etc. • *Ethics and law*: Regulations, standards, laws, moral and ethical issues. • *Other socio-material contexts*: Built environment, impact on the natural environment, local economy, education system. • *Additional considerations*: Political aspects (under ethics and law), Profitability, and Ability to own or produce the technology in a financial sense.

A. Participants

In Spring 2021 and Spring 2022, 38 undergraduate students from various engineering majors self-enrolled in a one-credit course called Humanities-Informed Engineering Projects (class group) (see course description in section II). In addition, we collected data from 62 undergraduate students who did not enroll in the course: 32 engineering students from different engineering majors (engineering group) and 30 students from different humanities majors (humanities group). All students in the course participated in the assessment as part of the class. Students in the engineering and humanities groups volunteered to participate after receiving a recruitment email distributed to known engineering and humanities contacts and using a snowball approach. They received gift certificates for their participation. The Purdue University IRB approved this investigation.

B. Data Collection

All participants responded to a scenario-based assessment at two points in time: the start (pretest) and end (posttest) of the semester. We collected data using an online questionnaire, and only the students who completed both the pretest and posttest assessments were included in this study. Upon collecting the data, we deidentified student responses prior to scoring them.

1) ECP scenario-based assessment.

To assess students' sociotechnical thinking, we used the Energy Conversion Playground (ECP) scenario-based assessment developed by Mazzurco & Daniel (2020). The ECP assessment measures sociotechnical thinking along three dimensions (see Table 1): Technology, People, and Broader Context. These dimensions explore both the technical and contextual aspects of defining and solving a problem. Student responses to the scenario-based assessment were scored on a scale of 0 to 3 for each dimension as per the rubric given in Mazzurco & Daniel (2020). For more details on the scenario, see Fig 1.

> In developing countries, energy production is one of the most critical problems. Resources and technologies to produce energy are not often available. Thus, human power conservation systems might be used to power small appliances. Imagine you and your team are assigned to a design project in partnership with a Non-Governmental Organization of a developing country. The NGO needs a low-cost power system that can generate enough energy for the lights of a primary school. One of the members of your team suggests using a merry go round, seesaw, and swing to produce energy that can be converted to electricity for the lights.
>
> **Question**: What considerations do you need to take into account to solve the problem described in the scenario? List and describe all the constraints and justify their inclusion

Fig. 1. Energy Conversion Playground scenario developed by Mazzurco & Daniel, (2020) .

We chose to use a scenario-based assessment because these assessments allow some insight into students' thinking and may more directly measure students' abilities than traditional self-report assessments (Davis et al., 2023). Furthermore, scenario-based assessments can be used as an instructional tool as well as an assessment tool (Davis et al., 2023). The course we studied for this project used case studies to teach students to

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consider and integrate both technical and contextual factors (i.e., practice sociotechnical thinking) while problem-solving. Because the ECP is a scenario-based assessment that measured this skill, it aligned well with the objectives of the course and research study. In addition, earlier studies that compared two scenario-based assessments and found that the ECP may be better suited for assessing sociotechnical thinking over a semester-long course when compared to another similar instrument (Joshi et al., 2022).

C. Data Analysis

To compare students' performance on sociotechnical thinking across the three groups, we examined participants' pre and posttest scores on the ECP scenario-based assessment. We deidentified the data by removing participant information such as names, majors, and emails before analyzing the students' responses. Three researchers from our team scored all student responses to the scenario using the ECP rubric (see Mazzurco & Daniel, 2020) and then met to discuss the scores until they reached a mutual consensus on the final score for each response.

Next, we conducted three 3 x 2 mixed ANOVA analyses to answer the two research questions. The advantage of using mixed ANOVA is that it allows analyses of both the within-and between subject variables (i.e., changes over time and changes between groups) (Frey, 2018). For this study, as we wanted to analyze changes over time and changes between groups, a mixed ANOVA was suitable for our study.

Group	Time	
	Pretest	Post test
Treatment: Class	Technology	Technology
Control I: Engineering	Technology	Technology
Control II: Humanities	Technology	Technology

Group	Time	
	Pretest	Post test
Treatment: Class	Broader Context	Broader Context
Control I: Engineering	Broader Context	Broader Context
Control II: Humanities	Broader Context	Broader Context

Group	Time	
	Pretest	Post test
Treatment: Class	People	People
Control I: Engineering	People	People
Control II: Humanities	People	People

Fig. 2. 3X2 Mixed ANOVA Matrix for each dependent variable: Technology, People, and Broader Context

As shown in Fig. 2, the dependent variable for each ANOVA is one of the three dimensions of the ECP instrument (Technology, People, and Broader Context). Across all three analyses, the between-subjects factor was 'group-membership' in one of the three student groups: class group, engineering group, and humanities group. The within-subjects factor was 'time,' consisting of two levels: pretest and posttest. We checked that our data met the assumptions of this analysis, as described in the following sections.

D. Assumptions for 3x2 Mixed ANOVA

1) Normality

Our results of the normality test indicated that no sociotechnical thinking dimensions across the three groups were normally distributed. Hence, the non-normality of the data for the three groups could impact proceeding hypothesis testing as the mean may not appropriately represent the distribution. However, the central limit theorem suggests that for a random sample size greater than 30, the standard sample mean converges to a normal distribution with a mean equal to the sample mean (Islam, 2018). Hence, we satisfied the normality assumption as the sample size of all groups is greater than 30.

2) Homogeneity of Variances:

Next, we calculated the variances for pretest and posttest dimensions of sociotechnical thinking using Levene's test of homogeneity of variances (See Table II). We found significant results for the Broader Context Pretest score. For the other dimensions of sociotechnical thinking at pre and posttest, the homogeneity of variances is non-significant. This indicates that we can assume equal variances for the data except for Broader Context pretest score. The results of the study for Broader Context pretest score dimension will thus need to be interpreted based on the assumption of unequal variances.

TABLE II
TESTS OF HOMOGENEITY OF VARIANCES

		Levene Statistic	df1	df2	p
Technology Pretest	Based on Mean	.309	2	97	.735
Technology Posttest	Based on Mean	.943	2	97	.393
People Pretest	Based on Mean	2.363	2	97	.100
People Posttest	Based on Mean	1.723	2	97	.184
Broader Context pretest	Based on Mean	4.740	2	97	.011*
Broader Context Posttest	Based on Mean	2.051	2	97	.134

* = p <.05

3) Sphericity of our data

For this study, as we have two levels of within-subjects variable, there is only one set of differences (pretest vs. posttest) and hence, sphericity is not an issue (Field, 2013). Therefore, we can assume that the assumption of sphericity has been met.

E. Limitations

The ECP scenario-based assessment used in this paper is not developed based on the humanities-informed engineering framework from Davis et al., (2021). Therefore, the pedagogical framework used for fostering sociotechnical thinking is not the same as that used for developing the assessment instrument. However, there are overlapping contextual constructs between the framework and assessment instrument. Further, given the sample size for each group, it may not accurately represent the interactions with a high statistical power.

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IV. Results

In this section, we describe the descriptive statistics of our pre/post data followed by interpretation of results in response to each research question.

A. Descriptive Statistics

The data for this study are pre/post scores of three sociotechnical thinking dimensions for three student groups (Table III).

TABLE III
DESCRIPTIVE STATISTICS

Dimension	Group	N	Pretest M	Pretest SD	Post Test M	Post Test SD
Technology	Class	38	2.42	0.56	2.29	0.73
	Humanities	30	2.23	0.77	2.30	0.65
	Engineering	32	2.50	0.67	2.47	0.51
	Total	100	2.39	0.68	2.35	0.64
People	Class	38	0.84	0.89	1.32	0.84
	Humanities	30	1.27	1.06	0.70	0.75
	Engineering	32	0.44	0.72	0.62	0.66
	Total	100	0.84	0.94	0.91	0.82
Broader Context	Class	38	0.42	0.55	0.87	0.84
	Humanities	30	0.33	0.55	0.30	0.60
	Engineering	32	0.22	0.42	0.34	0.54
	Total	100	0.33	0.51	0.53	0.73

From Table III, we observe that the mean scores show an increase from the pretest to posttest for People and Broader Context dimensions of sociotechnical thinking for the class group. The students from the other two groups did not change much in their scores of Technology, People, and Broader context from the pretest to the posttest. This trend was expected as these students did not receive any training on sociotechnical thinking between the two assessment times. In addition, the mean scores of the class group students decreased on the dimension of technology from the pretest to the posttest as students focused more on contextual considerations (like People and Broader Context). Observing the spread of the data, we can infer that the posttest scores seem to have a greater spread for the majority of the sociotechnical thinking dimensions compared to the pretest data.

B. Research question 1: How do the scores on a scenario-based assessment of sociotechnical thinking compare between students enrolled in a humanities-informed engineering course and control groups of engineering and humanities students (not enrolled in the course)?

We used between-subjects ANOVAs for each of the three dimensions of sociotechnical thinking to address research question 1. The between-subjects ANOVAs test the difference between the three groups while ignoring the time variable. That is, this analysis considers the pre- and posttest scores of each group together when comparing across groups. We found no statistically significant difference in scores for the Technology dimension across the three groups $(F(2,97) = 5.714, p < 0.247, \eta_p^2 = .28)$. However, there were statistically significant differences for the People $(F(2,97) = 5.714, p < 0.05, \eta_p^2 = .128)$ and Broader Context $(F(2,97) = 6.521, p < 0.05, \eta_p^2 = .119)$ dimensions, which indicated that students from the three groups had some differences on these two dimensions of sociotechnical thinking.

Next, we used Tukey's post-hoc tests to determine which pairs of student groups had statistically significant differences in their scores for the People and Broader context dimensions (see Table IV). For the Broader Context dimension, we found a statistically significant difference between the ECP scores for the class group and both the engineering control group $(p < 0.01)$ and the humanities control group $(p < 0.05)$, where the class group had higher scores than both groups. For the People dimension, we found a statistically significant difference between the ECP scores for the class group and the engineering control group $(p < 0.01)$, where the class students scored higher on average. We also found a difference between the two control groups for the People dimension, where the humanities students scored higher than the engineering students $(p < 0.05)$.

TABLE IV
POST HOC ANALYSIS -TUKEY'S FOR BETWEEN-SUBJECTS EFFECTS PEOPLE AND BROADER CONTEXT

Measure	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	P.
People	Class	Humanities	.10	.155	.811
	Class	Engineering	.55	.152	.001***
	Humanities	Engineering	.45	.161	.017*
Broader Context	Class	Humanities	.33	.114	.014*
	Class	Engineering	.36	.112	.005**
	Humanities	Engineering	.04	.119	.952

* = p <.05, ** is p< .01, and *** is p<.001

C. Research Question 2: How do the scores on the scenario-based assessment of sociotechnical thinking change from pretest to posttest for the students in the course group and the two control groups?

We used within-subjects ANOVAs for each of the three dimensions of sociotechnical thinking to address research question 2. Within-subjects ANOVAs can explain (i) whether there is a difference between the pre-and posttest scores for all the students together (across all three groups) (ii) the interaction effect between time and group-membership i.e., how much do differences in scores on the sociotechnical thinking dimensions between the three groups change over time (pretest to posttest).

When considering all the students together, our within-subjects ANOVAs identified no statistically significant differences in the ECP scores over time for the Technology $(F(1,97) = 0.147, p = .702, \eta_p^2 = 0.002)$ and People $(F(1,97) = 0.087, p = .769, \eta_p^2 = 0.001)$ dimensions of sociotechnical thinking. For the Broader Context dimension, there was a statistically significant increase in the students' scores over time $(F(1,97) = 5.359, p < 0.05, \eta_p^2 = .052)$.

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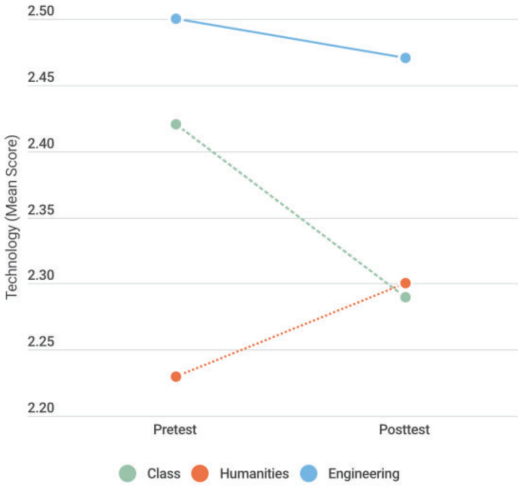

Fig. 3. Change in Means from Pretest to Post Test for Technology dimension.

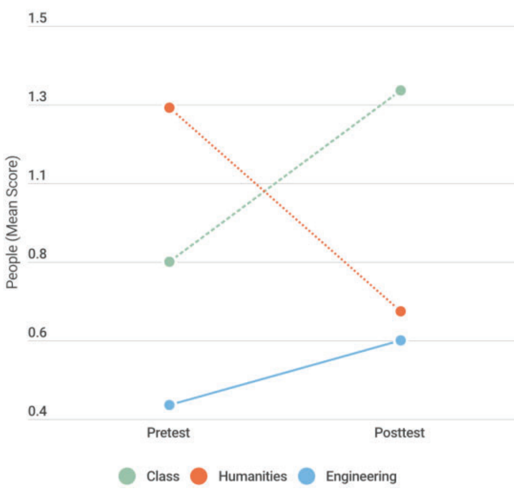

Fig. 4. Change in Means from Pretest to Post Test for People dimension.

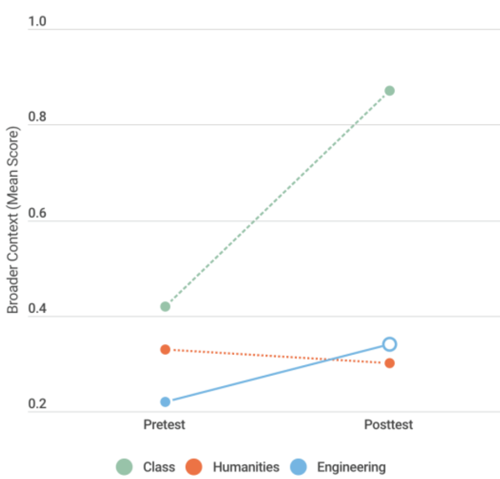

Fig.5. Change in Means from Pretest to Post Test for Broader Context dimension.

When we considered the interaction effect between time and group membership, we found no statistically significant effect for the Technology dimension. However, for the People ($F(2,97) = 8.308, p < 0.001, \quad \eta_p^2 = .146$) and Broader Context ($F(2,97) = 3.469, p < 0.05, \eta_p^2 = .067$) dimensions, there was a statistically significant interaction effect between time and group membership. This effect indicated that the scores for some of the groups changed at different rates from the pretest to the posttest for these dimensions.

To further explore the impact of the interaction effect, we observed how the means vary at the pretest (Time 1) and posttest (Time 2) for all three student groups (see Fig. 3, Fig. 4, Fig. 5.). In Figure 3, we can see that there is little change in the Technology dimension scores over time for the three groups. This observation aligns with our within-subjects results suggesting that there is an interaction effect between time and group membership for only People and Broader Context dimensions. For the People dimension (Figure 4), we notice that students from the class group showed a large increase, the engineering group showed a slight increase, and the humanities showed a considerable decrease in their scores over time. Though the decrease may not seem much, it is large as the scale of scoring varies from 0–3. Similarly, in Figure 5 we see that the class group students showed a large increase in their scores over time on the Broader Context dimensions while the engineering group students showed a slight increase, and the humanities group students showed a slight decrease. Overall, the students in the class showed the most increase amongst the three groups over time on the dimensions of People and Broader Context.

V. Discussion

The purpose of this study is to compare the performance of students enrolled in humanities-informed engineering class with students from engineering and humanities majors who did not enroll in the class to investigate (i) how the scores between three groups compare on dimensions of sociotechnical thinking (ii) how the scores of the three groups change over the course of a semester. To compare the student performance, a scenario-based assessment was administered to three groups of students at the start and the end of Spring 2021 and Spring 2022 semesters. To answer the research questions, we conducted three 3 x 2 mixed factorial ANOVAs, one for each sociotechnical thinking dimension — Technology, People, and Broader Context.

In response to RQ1, we found that the class group scored higher on the Broader Context dimension than both control groups and higher on the People dimension than the engineering control group. The humanities control group also scored higher than the engineering control group for the People dimension. In response to RQ2, we found that student scores increased over time for the dimension of Broader Context. Additionally, there were differences between the groups on the People and Broader Context dimensions from pretest to posttest.

Our results suggest that completing the humanities-informed engineering course may improve engineering students' sociotechnical thinking by helping them to consider contextual aspects while problem-solving. This result aligns with Frank's (2010) study which found growth in systems thinking abilities with interdisciplinary education. Our comparison between the two control groups also support previous findings that humanities students are more likely to consider human aspects of problems because their education integrates various social and contextual factors (Benneworth, 2015). At the same time, the lack of change in Broader Context scores for the engineering group students supports previous findings that traditional engineering education largely prioritizes technical aspects (Trevelyan, 2007) and discounts contextual aspects (Cech, 2014; Faulkner, 2007; Paul et al., 2022; Riley, 2008).

Future research could focus on ways in which the traditional engineering curriculum can integrate contextual aspects The results of our study suggest that interdisciplinary training in humanities can improve engineering students' sociotechnical thinking, but only a limited number of students take this interdisciplinary course. The rest of the engineering education curriculum still focuses on teaching technical dimensions rather than social dimensions (Cech, 2013; Faulkner, 2000; Pawley, 2009), despite technical engineering decisions responding to and influencing the society. This lack of focus on social and contextual aspects limits engineering students' sociotechnical thinking abilities and thus, they marginalize contextual aspects while solving problems (Riley, 2003, 2008; Stevens et al., 2014). To overcome this challenge, a broader curricular shift is necessary to enable all engineering students to develop sociotechnical thinking abilities. Rather than having an elective course on this topic, all engineering courses could integrate contextual topics related to the course content. This approach could support students' development of sociotechnical thinking to a higher degree because they would see relevant content across the curriculum.

Building on this suggestion, future research could explore the effect of the duration of interdisciplinary or sociotechnical interventions on students' development of sociotechnical thinking. The current work emphasizes that brief exposure, through a semester-long course, shows positive results for including contextual aspects in engineering problem solving. However, training over an extended time may be more effective in producing gains or those gains may be more stable. These unexplored questions are important in understanding how to prepare engineering graduates to maintain a sociotechnical focus rather than a purely technical one. Furthermore, as integrating contextual and technical dimensions is an important component of engineering, future research should continue to explore how experiential learning opportunities with socially embedded experiences (like service learning) administered over different periods impact sociotechnical thinking in engineering students.

Along with these interventions, researchers can also explore the development of instruments to assess sociotechnical thinking in students and practicing engineers. Currently, limited tools like the ECP scenario (Mazzurco & Daniel, 2020), Abeesee scenario (Grohs et al., 2018), and Lake Urmia Vignette (Davis et al., 2020) are available to assess students' sociotechnical thinking abilities. Additional research is needed to identify ways to effectively assess sociotechnical thinking abilities in real-world settings (e.g., service learning or internship programs). It may also be useful to explore pedagogical frameworks that can simultaneously be used to teach as well as assess sociotechnical thinking.

VI. Conclusion

Our study explored the sociotechnical thinking skills of three groups of students over the course of a semester. We administered the ECP scenario-based assessment to students enrolled in humanities-informed engineering course and two control groups: engineering students and humanities students. Our results indicate that students from the course saw greater increases on their assessment scores over time when compared to the two control groups. These findings suggest that interdisciplinary education can help foster sociotechnical thinking abilities in engineering students. Future research could explore pedagogical frameworks and assessments on sociotechnical thinking and observing the effectiveness of these techniques over an extended period.

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