Paper Title Efficacy of Humanities-Driven Science, Technology, Engineering, and Mathematics Curriculum on Integrating Empathy Into Technology Design

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1. Objectives

In the past decade, there have been calls in the teaching of engineers to touch on the so-called "soft skills," to produce more well-rounded students; one such skill that has been the focus of this discussion is empathy (Hess et al., 2016; Walther et al., 2017). Empathy, tied to critical thinking (Ahern et al., 2019; Paul & Elder, 2005), design thinking (Jamal et al., 2021; Lloyd & Busby, 2003), and ethical dispositions outside the classroom (Baillie & Catalano, 2009; Zoltowski et al., 2012). However, engineering curricula often fail to include empathetic thinking (Adams et al., 2011; Sochacka, Guyotte, & Walther, 2016; Strobel et al., 2013), and in fact, out of all disciplines, engineering is perceived to be one of the most unempathetic disciplines (Xu et al., 2021), and students in engineering programs consistently score lower than other disciplines on instruments designed to measure empathy (Rasoal et al., 2012) . Some studies suggest that disciplines in the humanities are better poised to teach empathetic thinking (Baillie & Catalano; Zoltowski et al.).

In this ramp-up study from a project previously reported at AERA 2021, authors investigate the effectiveness of a co-taught, hybrid humanities-engineering course (called humanities-driven STEM, or HDSTEM) taught across two universities in facilitating performances of empathy from students. Using primarily discourse analysis, we determine that students generally make small gains in their ability to position themselves empathetically within their coursework.

2. Perspectives/frameworks

Discourse: Guiding this study, especially analysis, is the theory of discourse. We rely heavily on Gee (2014; 2015). Gee suggests that there are two types of discourses: big-D "Discourse" and little-d "discourse." Little-d discourse is language in use. It is the way individuals speak, the choice of words, arrangements of words, and inflections they employ when speaking or writing. These choices must take into account big-D discourse. Big-D discourse refers to "the ways in which such socially-based group conventions allow people to enact specific identities and activities" (2015, p. 419). In other words, the ways that we speak follow certain generic conventions for the contexts in which we occupy. There is no one overarching big-D discourse, but many, reflective of the values and beliefs shared by different social groups. In this way, the language that people choose to use is reflective and performative of an identity that they wish to convey. Fluency with a particular discourse suggests identification as such and such a person.

Empathy: An additional construct important to this study is empathy. We recognize that empathy might manifest in various ways, and in fact, scholars speak of different kinds of empathy: mentalizing or cognitive empathy (I can logically understand why someone would feel or react a certain way) (Pino & Mazza, 2016); character identification (I relate to another person and their story) (Keene, 2006; van Krieken et al., 2017); situational empathy (I have

experienced a similar situation that another person is experiencing) (Ekund et al., 2009); and moral empathy (I recognize why others might view something as right or wrong) (van Krieken et al.). The broader concept here is understanding why one might believe or feel a certain way, or, to employ an overused but appropriate phrase, to place oneself in another's shoes. These various kinds of empathy served as a framework to guide our analysis.

3. Method

Assuming that language performs certain kinds of identity (Gee, 2014), we analyzed participants' first and last assignments from the HDSTEM courses. Specifically, we focused on the introductions or "define" sections, as these were the sections that were modified during the EDMAIC assignments, and we wanted to see if, over the trajectory of the course, students changed the ways that they defined their problems after having been encouraged to empathize as a part of this process. Discourse analysis focuses on the structures and choices of individuals' language. At Gee's suggestion, we asked how certain verbal choices created a performance of empathetic identity for participants.

Gee (2014) provides a discourse analysis "toolkit." He suggests first arranging text into stanzas, as a way to isolate words and phrases and arrange them to more carefully look at how they exist both independently of, and how they interact with, one another. Once this is done, he suggests looking at/for various aspects of the language used, including instances of deixis (words that do not have a stable referent, such as pronouns or locutionary words like "here" or "there") and examining what specifically these words refer to; the arrangements of subjects of sentences and their predicates; examining speech acts (looking at what an utterance performs or is intended to achieve); asking "why this way rather than another way" of language; considering the contexts within which language is uttered; and thinking about the identities that one seems to be conveying through their discourse based on what we know about larger Discourses and languages that they use. Using these tools, we read each turned each assignment into stanzas and wrote analytic memos to see what they told us about the language in use and the ways that it constructed a student's identity. Authors paired with one another to compare and reconcile interpretive differences across the data.

As a triangulation measure, to affirm the findings of our discourse analysis, we scored assignments on a scale of 1-4 using the empathy section of the AAC&U VALUE rubric for intercultural knowledge and competence. For each participant, two researchers scored the assignments, and Pearson's r was used to determine interrater agreement in terms of the degrees to which we saw a rise or fall (or stagnation) in empathy level.

4. Data Sources

Data come from three sections of HDSTEM courses taught at two different universities: one section was taught to an honors cohort (students comprising a mix of majors) at a Southern Plains R1 university in 2019 and again in 2022, and another was taught to a cohort of primarily engineering students at a northeastern R2 university in 2022. Within the course, students completed four assignments in which they were instructed to choose a technology emerging from the WWI-WW2 era and reverse engineer it using the Six Sigma method of Define a

problem, Measure the extent of this problem, Analyze, Improve, and Control (DMAIC) method. For the second and third assignment, students were further instructed to add an additional step commonly taught in design-thinking (Jamal et al., 2021): empathize. Here, students were instructed to think about the needs, wants, and desires of those whom the chosen technology might affect, as well as the social and political backdrop of the technology. We compare the first and final DMAIC assignment from students (where they were not instructed to empathize) to see if there were differences in the ways that students positioned themselves and performed potentially empathetic rhetorical moves in their writing.

In total, we collected data from 23 students across the three sections of the HDSTEM course (five from the 2019 R1 honors cohort, five from the 2022 R1 honors cohort, and 13 from the 2022 engineering cohort). Two did not complete their assignments and we were unable to compare them, giving us a total of 21 students. Of the remaining 21, only two were female.

5 Results

Due to length constraints, we are unable to provide a full example of discourse analysis on an assignment. However, here, we provide some recurring themes that we noticed across assignments and provide brief examples of how they appeared in assignments (note: all names are pseudonyms).

Often, especially in the opening assignments, students presented themselves as a "neutral expert." What stood out in our analyses was how certain students offered in-depth historical and contextual details about a topic as a way to avoid expressing explicit partiality in their 'Define' sections. We see this 'sticking to the facts' method in Manny's first assignment where details the many military uses of rubber through precise measurements allotted to different sectors of the war effort and only names America as the side in need of this resource. In his final assignment, Dilbert establishes the long history of submarines "before, during, and after" WWII and connects their importance to the eventual development of relevant countermeasures, but only names a side in his penultimate stanza via a relatively neutral citation about Allied U-boats. While remaining neutral might appear less empathetic at first glance, it could be argued that students who prioritize the facts and work to establish a foundation of truth are invested in ethical decision making ahead of partiality when introducing their problem. Still, this would be less empathetic than considering and commenting on various stakeholder roles related to their topic.

Another aspect that set students as neutral experts, especially in the early assignments, was discovered through the subject/predicate tool. Students often used subjects that were inanimate items along with the passive voice to convey points, so that the problem was primarily technical, rather than "human." An example of this is Sherman's use of "Autonomous diving gear was originally developed in 1925" to begin his first assignment. Here, the attention is on diving gear itself, rather than those who invented it, (a more active statement would be "scientists invented autonomous diving gear…"). In this case, the language

supplants the human and calls attention away to the human element of the topic. Generally, we regarded this as less empathetic.

Another theme that was evident across our analyses were the various ways students invited their readers to join them on their problem-solving journey. Both Gary and Lars draw their audiences in with the subject pronoun "we" several times in their 'Define' writing which has a persuasive effect on the audience to invest in the outcome as a team. Lars takes this strategy a step further in both of his assignments by posing a rhetorical question in his final stanza, again inviting his audience to consider the problem collectively. This approach works to bring the reader in and allow them to consider the dilemma from multiple perspectives. These rhetorical moves found in the later iterations of the DMAIC assignments showed an empathetic disposition toward collaboration and invoked a sense of shared engineering with the intended audience.

As assignments progressed, we began to see more human-oriented language. Further, generally, contextual/historical information began to examine the motivations, desires, and traits of nations and peoples, rather than cold facts such as the measurement of rubber. Kyle's final assignment, for instance, considered not only the concerns of engineers and scientists involved in the Manhattan Project, but considers the reasons Germany was not concerned about a nuclear weapons program, and additionally comments on the potential drawbacks of nuclear science (death and suffering), but the benefits as well (practical and peaceful uses). Additionally, we saw an average improvement of approximately .4 in empathy scores based on the AAC&U VALUE rubric. Interrater reliability was moderate ($r = .68$) and significant ($p = <.001$) across rubric scores. Furthermore, though there was not 100% agreement between raters, there was nearly 100% agreement among raters that a participant expressed more empathy between assignments 1 and 4 than expressed less empathy, or stayed the same (the one exception was a rater that judged a participant as staying the same, while the other rater saw a drop in empathy levels).

6 Scholarly Significance

In two universities, R1 and R2, empathy scores both increased between assignments 1 and 4. On average, however, students from R1 University showed higher empathy scores between assignments 1 and 4 (about 0.917) than students from R2 University (about 0.67). It is evident from the similar increase across different universities and instructors that empathy does not depend on certain contexts, but rather on hidden common characteristics among participants that can be revealed and discovered in situations that call for empathy. However, the difference may be a result of discursive norms across contexts. Based on findings, we know that engineering students have the ability to take perspectives, however, discourse theory suggests that we need to make space and normalize this kind of thinking and language within engineering programs.

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