Systematically Integrating Liberal Education in a Transdisciplinary Design Studio Environment

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Abstract

Many scholars have cited the importance of integrating humanities and social science content into engineering and technology education, noting the value in building students' deep competence in communication and interpersonal skills, including an understanding of how technology is intertwined with societal and human needs. However, there is relatively little guidance as to how viewpoints and content from liberal education perspectives might be integrated systematically into a single, transdisciplinary learning experience that allows students to view the world through different lenses from a variety of disciplinary perspectives while locating and synthesizing information crucial to solving interesting and worthwhile problems that may not be obvious from a solely technical or solely humanities perspective. In this paper, we present a case study including multiple iterations of a learning experience that integrates liberal education, design, and technology content and forms the core of an undergraduate transdisciplinary degree program. Using an ethnographic approach, we trace the evolution of students' and instructors' perceptions and intentions in relation to integrating liberal education, and document these perspectives through interviews, focus groups, and course observations.

Introduction

Oberst and Jones[1] argue that today's engineering students should understand the impact of their work within the framework of a "growing social consciousness around the world" (p. 8.846.9), echoing a humanist shift in understanding engineering as already intertwined with human needs, values, and societal systems (e.g., [2,3]). A variety of disciplinary perspectives from humanities and social science traditions play a strong role in preparing well-rounded, socially responsible graduates[4], yet the highly siloed nature of higher education has made the tight integration of such approaches difficult to achieve in a systematic way on both a course and program level.[6,7]

Scholars have cited the importance of integrating humanities and social science content into engineering and technology education, noting the value in building deep communication competence and an understanding of how technology relates to society and human needs (e.g., [3,8]). Some approaches focus on the development of courses that run in parallel to traditional professional formation experiences, encouraging students to synthesize learning about humanities-related topics in a cross-disciplinary framing, where liberal education courses are distinct and separate from their technically-oriented project work. These approaches do not appear to have been successful in encouraging students to truly integrate what is learned in technology coursework with what is learned within and across traditional liberal arts subject areas. However, there is relatively little guidance as to how explicit viewpoints and content from multiple liberal education perspectives might be intentionally and systematically integrated into a single, humanities- and technically-focused learning experience. This paper examines how these perspectives may be encouraged by designing a transdisciplinary program that aims to integrate liberal education and technology skills and knowledge.

Related Work

Humanist Approaches to Engineering Education

There have been repeated calls for incorporating humanistic perspectives into the education of engineers, recognizing the inherently social nature of many engineering challenges.[9-17] On a program level, the engineering community has been encouraged to recognize such professional skills, with specific ABET criteria that address the ability to communicate effectively; understand the impact of engineering solution in global, economic, environmental, and societal contexts; engage in lifelong learning; and to function effectively on multidisciplinary teams.[5] Some educators envision liberal education integration that addresses these goals by introducing or adding non-technical subjects into already existing courses without any further changes—a cross-disciplinary approach that regards the integration of liberal education as "enhancement" (e.g., [13,14]). Others prefer collaboration across multiple disciplines to develop a new curriculum—a multi-disciplinary or transdisciplinary approach.[14] Still others use specific liberal education lenses, such as empathy,[16] as a perspective through which to view integration.

Programs across the integration continuum have had varying results. Indeed, integrated engineering curricula allow learners to significantly improve humanities-related professional skills in cross-disciplinary programs,[10,14,18] avoiding curricular repetition,[14] and encouraging closer student-faculty connection and mentoring that enhance learners' sense of community.[19] Froyd & Ohland[14] also highlighted the importance of collaboration among faculty with diverse backgrounds to ensure appropriate integration of liberal education concepts. Such collaboration should be egalitarian in order to support an equal and free exchange of ideas. However, there is a continuing concern that a humanist approach to learning in engineering and technology should take on humanistic concerns without attempting to replace or "colonize" liberal education.[20]

The integration of liberal education perspectives not only facilitates engineers' ability to address complex, ill-structured problems that have a social dimension (i.e., humanistic), but also allows for a critique of the technical limitations built into much of the engineering discipline—for instance, the gendering of technical knowledge and a larger engineering and technology community that often excludes women and minorities from the conversation (c.f., [21,22]). Thus, the integration of liberal education impacts not only curricula, but also faculty and student expectations and roles within that curricula.

Making Learning Whole

As engineering educators seek to build students' awareness of "wicked," ill-structured problems, they must move from primarily technical challenges to complex, socially-situated challenges that have a complex array of overlapping interactions that are both technical and humanistic.[11,23] Such problems require new pedagogical and instructional models that can account for such complex, holistic approaches to systems, preparing students to meet 21st century challenges.[24]

Creative interdisciplinary learning experiences have been designed with the intent of incorporating liberal education into an engineering context while effectively retaining disciplinary knowledge. Examples of this interdisciplinary integration include: using a case study of Paul Revere to integrate materials science and the history of technology;[25] engaging in service learning projects to allow engineering students to experience the messiness of complex social

problems;[26] and, incorporating science fiction into a nanotechnology course using activity-based experiential learning to look at potential impacts on society.[27] In addition, constructivist-inspired project and problem-based learning experiences (PBL) attempt to create more realistic, real-world learning environments focused on solving ill-structured problems, resulting in some promising outcomes.[28]

The integration of multiple disciplinary perspectives requires students to effectively transfer their learning from one disciplinary context into another. However, a lack of transfer in technology education is common (e.g., [29]) and may be partially explained by students' inability to apply what was learned in one situation to another one due to perceived differences or similarities between the two experiences.[30] Salomon and Perkins[31] suggest that for higher level transfer (i.e., high-road transfer) to happen beyond automatic, well-practiced behaviors (i.e., low-road transfer), learners need to exercise mindful abstraction—"deliberate, usually *metacognitively guided* and effortful, decontextualization of a principle, main idea, strategy, or procedure" (p. 126, emphasis added)—to create a connection between such experiences and to generate a lens used to view, analyze, and solve a novel problem. Yet, to expect that such a process would occur on its own without a purposeful initiation of mindful abstraction would be naïve, as learners tend to passively receive information unless actively engaged.[31] For this reason, Engle[32,33] suggests the importance of social framing, where activities are framed to allow an intended connection between what is learned and the transfer context (i.e., intercontextuality), and students are reminded and encouraged to generalize to a new situation or setting. Lobato[34] argues that it is not the multiplicity of contexts that impact the transfer, but rather purposefully drawing of students' attention towards patterns and properties between the contexts.[35]

Method

A summary of participants in the program within each semester covered are shown in Table 1. Data sources for this project come from a multi-year research effort, comprising regular interviews of students and instructors, focus groups with students, collection of syllabi, and regular classroom observations of past and current learning environments. Our data analysis draws primarily on course experiences from the current synthesized learning environment as reported by students and instructors through interview and focus groups, building upon past approaches to integrating humanities content in this degree program. We rely upon our extensive engagement with the program learning environments to construct the case study reported below, using an ethnographic approach[36] to understand and document both the development of the course structure and the student and faculty experiences within these courses over time. We draw on the critical ethnographic approach described by Carspecken,[36] which includes multiple stages to: 1) build the primary record, 2) perform reconstructive analysis, 3) engage in dialogical data collection, 4) and establish system relations. For the purpose of this case study, exemplary or illustrative quotes and observations were included to provide a sense of the program and participants, which largely draw on work in stages 1-3. As a research team, we have continuously engaged in participant observation of the learning environment (Stage 1), using strip analysis and other forms of reconstruction of meaning (Stage 2) to inform dialogical data collection that strengthens our interpretations of portions of the learning experience (Stage 3). In this paper, we do not address any concerns that explicitly engage with system relations or the impact of system relations on the learning experience.

Table 1. Instructors and students engaged in the program by semester.

Semester	# of Instructors (subset of program fellows)	# of Students Enrolled
Fall 2014	7 (5 seminar; 2 design lab)	33
Spring 2015	5 (2 seminar; 3 across 2 design lab-like experiences)	13
Fall 2015	4 (2 seminar; 2 design lab)	8
Spring 2016	4 (4 seminar, not all present for all sessions; 2 design lab)	7
Fall 2016	3 (merged experience)	8

Integrating Liberal Education and Technology: A Case Study

The context of this case study is the development of a technology-focused, transdisciplinary program at a large research-intensive Midwestern university. This program is part of a larger initiative supported by the university to experiment with new educational approaches. The vision for this initiative was to prepare students to succeed across their future career—which may include jobs that do not exist today. A group of interested faculty fellows were charged with investigating new educational approaches that met the values of: (a) viewing the student as a whole person; (b) welcoming diversity and access for all; (c) student autonomy; (d) risk-taking as an important component to learning; and (e) openness fostered through sharing, transparency, and collaboration.[36] In the Fall of 2013, a group of faculty were recruited from multiple colleges across campus, and worked to develop a shared understanding of various educational models and the 21st century skills desired by employers. Ultimately, the fellows felt the only way to accomplish such a goal was to take a transdisciplinary approach,[38] breaking down traditional disciplinary silos by partnering with faculty from around the university to develop learning experiences that required the incorporation of knowledge and skills from multiple disciplinary perspectives.[7] Under this vision, development of transdisciplinary skills, including technical and non-technical knowledge, would occur within a set of course experiences across the four year program. Faculty from multiple disciplinary backgrounds stressed the need for students to be exposed to multiple ways of thinking and making meaning, noting that the benefits of liberal education far exceed the writing, presentation, and teamwork skills often considered sufficient to augment technical content in preparing students to work in industry.

The group planned to merge pedagogical approaches traditional to the humanities (seminar) and visual and performing arts and design disciplines (studio). Each of these approaches would be used to help students integrate knowledge from both technical and liberal education domains. Faculty members' own experience with these models informed our initial vision of the learning experience. The initial intention was to create two distinct learning experiences—seminar and design lab—which would be augmented by relevant experience gained outside of the program through coursework, internships, travel abroad, and extracurricular activities.

Seminar. The goals of the seminar were to foster creativity, empathy, critical thinking, productive risk-taking, and communication skills across the domains. The experience was intended to create an open learning and discussion space, facilitated by the faculty, for students

to engage with multi-disciplinary topics across humanities, social sciences, and technology.[Error! Reference source not found.] Students would have opportunities to explore and address global issues using a range of disciplinary lenses and forms of knowledge with guidance and feedback from the faculty.

Design Lab. The goal of the design lab experience was to engage students in real-world, "wicked" projects that required the application of multiple skills and knowledge domains, using a studio model of instruction that encouraged a project-centered focus with regular formative feedback. This experience was envisioned to include a number of project sequences of varied lengths and complexity, with long projects that required students to "explore the elements of systematic approaches to problem solving, design, collaboration, and communication in great depth", while shorter projects would "allow [students] to practice systematic approaches in multiple contexts."[Error! Reference source not found.] Projects would increase in scope and complexity over time, becoming increasingly driven by students' interests and combinations of disciplinary knowledge.

Merging Existing Core Course Experiences (Fall 2014)

The pilot program was launched in fall of 2014. Political and institutional constraints made it difficult to implement our ideal vision for the first semester, which at the time was designed to have students spend most their credit hours within the pilot program. The seminar experience was offered as a seven-credit hour course block that included content from existing communications, English, digital technology, and information literacy courses. Digital badges were aligned with the learning objectives of each corresponding traditional course, and additional badges could be attempted by any student with an interest in other disciplines. The course was co-taught by five faculty members from English, Communications, Library Science, Computer Graphics, and Engineering Technology, all or many of whom were available during each class session.

The Design Lab was offered as a four-credit hour course and took the place of an introduction to technology and design course required for all freshman students in the college. This allowed Design Lab instructors to follow the model they had originally proposed, and focus badges around design-related competencies. The projects were intended to require students to engage with both technical and liberal education content. For example, the large team project for the semester required students to engage with the global problem of "food deserts." Students researched the concept of food deserts, how various plants are grown, and other related topics, devising a solution to some aspect of this problem. All student groups opted to pursue a "garden in a box" project to be used within an urban apartment setting. Students were required to apply (and, if necessary, acquire) technical knowledge related to hydrology, electrical engineering, and other disciplines, as well as knowledge about physics, chemistry, plant yields and growing conditions, the nutritional needs of a typical family, and an understanding of the context in which such a box garden would be placed. This course was co-taught by two instructors, one with expertise in Electrical Engineering as well as an interest in lighting and set design, and one with expertise in theatre scenic design, who had an interest in robotics.

While students enjoyed hands-on activities and "building stuff", they expressed concerns about lack of scaffolding and clear requirements regarding how they should proceed. Faculty also noted difficulties in coming to a common understanding among themselves of effective ways of

bridging diverse content domains. Faculty shared frustrations that students were not ready to be self-directed learners, requiring them to formalize instruction and assignments more than had been intended. Furthermore, it rapidly became clear to the program administrators that attempting to cover content from all possible combinations of disciplines offered across the university by our own faculty was not feasible. Tensions arose between liberal education and technology faculty, due to the perception of some liberal education faculty that they were "in service" to technically-oriented disciplines on the heavily engineering- and science-dominated campus. There was a fear that integrating humanities directly into technology-oriented courses may lead not only to decreased enrollment in required core courses offered by liberal education disciplines, but that the quality, rigor, and richness of students' experiences would be lacking if they were to enroll in courses which were designed and taught by individuals without deep disciplinary knowledge.

Parallel Liberal Education and Technology Course Experiences (Fall 2015-Spring 2016)

A revised model was developed, and ultimately submitted as a proposal for a degree-granting program. In this model, the concept of four years of Seminar and Design Lab courses was maintained, but the scope of these courses was further refined and less time and credit hours were allotted to each (2 credit hours for a two-hour-per-week Seminar and 3 credit hours for a six-hour-per-week Design Lab). These courses would cover 35% of required credit hours in a student's Program of Study. Another 25% of credit hours would be spent on courses aligned with the university core requirements and additional math and science requirements to support students' areas of interest, with the remainder of the credit hours devoted to disciplinary knowledge courses within student-selected focus areas. Students were expected to have at least one focus area in liberal education and one in technology.

Within this model, it was expected that students would bring in disciplinary knowledge from outside courses and apply this knowledge in increasingly sophisticated ways as they completed their Seminar and Design Lab projects. Seminar and Design Lab were consciously kept separate, as a way to provide students access to different pedagogical approaches, projects, and faculty. However, in principle, liberal education and technology perspectives would be addressed within both experiences. As one of the Seminar instructors explained:

> *We wanted them to see the humanities more ingrained in it so it wasn't like, "Oh now we're going to discuss humanities. Now we're going to discuss design." We had hoped that they would see how one informs the other. [...] The biggest theme [of Seminar in Spring 2016] was the trade-off aspect. We really wanted them to walk away having a good understanding that trade-offs occur in multiple settings, not just when you're talking economics, not just when you're talking about the environment, not just when you're talking about the internet, not just when you're talking about survival.*

A co-teaching model was intended to include at least one self-identified technical and one humanities-focused instructor within each learning experience. The Seminar would focus on students' understanding of the world and the arts, including seeing the world through a variety of lenses (*"thinking space, rather than making space"* as it was introduced to students on the first day of class in Spring 2016). The Design Lab would continue to challenge students to consider the needs of the users within authentic contexts, taking on a human-centered approach to design, which required rounds of user research as part of the students' design process. We expected

Seminar topics to inform students' Design Lab projects. However, students had difficulty connecting and transferring material between Seminar and Design Lab, although topics, assignments, and schedules were purposely planned together so that they could directly use what was learned in one in the other, and assignments were designed to be of reciprocal value. For example, students were encouraged to work on a design to meet a specific need in Design Lab, while creating a promotional video for the designed product in Seminar, and benefit from feedback received from both sets of instructors.

After the initial planning, the co-instructors of each of the two learning experiences would typically continue detailed planning of their assigned course in isolation from the other instructors, which often ended up in a misalignment of the experiences. While we expected students to connect complementary concepts, our cohort of students appeared to have difficulty doing so. For example, in one semester the Seminar focused on the concept of "tradeoffs", while in Design Lab students were presented with various techniques to consider constraints and design tensions. Many students reported confusion about their perceived disconnect between what was being covered in the two courses, and felt that a presentation of their Design Lab project in Seminar focusing on tradeoffs did not in any way assist them in furthering their project in Design Lab. Students found further difficulty in connecting lenses, such as a those presented in readings and discussions regarding feminist technology in Seminar and the concept of empathy for users in Design Lab, to their projects or their own lives.

Students continued to request additional clarity and consistency in expectations, which was due in part to intentionally broad or open-ended assignments designed to encourage self-directed learning. However, some student concerns were related to unintentional oversights, often due to unexpected and often subtle differences in understanding of terminology, techniques, and philosophy among faculty members with different disciplinary backgrounds. A lack of interest in reading and writing was also expressed by multiple students, especially those who saw themselves as more technically oriented. As one student explained, *"I guess on my part, I don't like reading, writing, especially like reading books."* Students were also concerned about workload, particularly for the seminar. One student expressed: *"they expect us to be, at least, somewhat competent with the whole entire article, so they're wanting us to read, you know, 2 and 3 articles that are like, 25, 30, maybe even 40 pages long, for a two-credit-hour class, in a week. Then we've got all this other stuff going on."* The fact that this course was only two credit hours (compared to the three-credit hour design lab) also concerned faculty, with some sense that the mismatch in credit and contact hours was also subliminally favoring technology and deprioritizing liberal education content and experiences. Students' negative reaction to Seminar and the themes presented within it appeared to carry over to Design Lab (or, at least, to not augment learning in the way we had anticipated). In this learning environment, students were designing alternative toilet solutions to be used in self-selected developing nations, and remained squeamish about gender-related concerns or design constraints, from physical differences between males and females, to the potential concern for women's safety in isolated facilities, settings, and cultures.

In Spring 2016, there was a purposeful decision to incorporate liberal education and technology perspectives into both learning experiences to foster a multi-disciplinary approach. This was explained by one faculty member as *"blur[ring] the boundaries that [students] often saw between seminar and design lab—simply stated as: seminar is for reading; design lab is for*

making." Students expressed surprise at what they perceived as changes in emphasis within the two courses in Spring 2016, including increased integration of readings, reading reflections, and discussion in Design Lab, and hands-on projects and introduction of tools that could be used to weigh trade-offs in Seminar. As one student expressed in a focus group, *"Well, I got to say, it's a lot more design in seminar and a lot more seminar in design."* Although some students indicated some sense of ambivalence regarding this change, all students in the other group agreed with one student's explanation:

> *It kind of feels like they've blurred the lines between our design lab and seminar. It's actually kind of nice because it makes it harder to differentiate between the two. I kind of liked the classes have somewhat blurred together just because it makes them feel like they're still a single part of the course, whereas previously it felt like, "Here's this part of the course, here's this course, here's this course." You have to take them in tandem but they don't quite make sense together.*

The Design Lab instructors deliberately included not only weekly readings, but also reading reflection assignments historically done only in Seminar. As one instructor explained:

> *The readings were picked to explicitly draw out transdisciplinary thinking. [...] Many of these readings [...] called out connections across what could be broadly construed as 'design', 'technology', and 'humanities'."*

For example, this instructor included readings on critical and reflective design, *"specific techniques for eliciting deep, tacit knowledge from users about social phenomena in a way that both allows the researcher access to users' thinking and increases users' explicit awareness of what is happening"* to allow students to explore "wicked problems" including data tracking, surveillance, intimacy and technology, and ethical use of technology. Again, some students saw the value in these approaches more than others. One student who had not been as active in class during previous semesters reflected:

> *I think last semester did a good job at explaining to us why [...] the best technological solution isn't always the best problem solver. I think that was a big thing to implement was that regardless of whether or not [...] I think last semester did a good job showcasing that what makes something successful is not necessarily that it's better. It's that people can use it better or willing to use it.*

Even though students felt the courses were more aligned than in previous semesters, they still tended to separate the courses in their minds. The fellows also noted that students tended to continue to view the faculty in simplistic, one-dimensional ways. For example, although one faculty member had a degree in library science and made herself available to help with information seeking and development of information literacy, she also held two engineering degrees and had significant hands-on experience. Despite her frequently approaching students to offer technical help, students rarely approached her for engineering-related assistance and went so far as to complain that there was no one available who could give them such assistance. Similarly, students repeatedly expressed surprise that a Seminar instructor whom they identified solely as an English instructor also had a degree in economics and could assist with topics

relating to economic impact, as well as providing practical assistance with tasks such as creating a budget.

Students would either disparage the lack of technical faculty or turn to another instructor they perceived as more "technical" for problems that may have outside that instructor's area of expertise. One student still relied on his first impressions from his freshman year, as he related:

> *The first day I was there I was like, 'Why wouldn't I go to [the engineering technology instructor] right now' I asked him a question kind of followed by, 'What are you here for?' He's like, 'I teach stuff.' I was like, 'No, no, no. If I want to get something, why do I go to you not [a humanities instructor]?' I established [that the engineering technology instructor] is very technical.*

The co-teaching model within the individual courses seemed to have failed to provide the desired underlying message: all the faculty have insights that they can we can offer based on their rich and varied backgrounds, and students should leverage these experiences to develop individual patterns of transdisciplinary thinking. Faculty members' recommendations for improvements varied widely. Some faculty, especially those with a formal background in instructional design, recommended a more structured four-year curriculum or learning experience model, with explicit development of transdisciplinary and metacognitive skills. Others felt that further experimentation with alternative pedagogies and topics would help us come to a more instructionally-sound solution. In Spring of 2016, faculty made an explicit decision to include more concrete projects in Seminar (e.g., building a Kickstarter page, creating a promotional video), and focus on socially-motivated topics and techniques in Design Lab that built upon humanities scholarship in relation to design (e.g., critical design, reflective design, user research).

Despite these changes, students continued to desire a concrete connection with specific specialties or skills offered by their instructors. As they struggled to build something, they tended to strike out and blame a perceived lack of technological skill on the part of instructors for their own inability or unwillingness to overcome a sort of builder's block. One student reflected on his understanding of the course instructors' expertise in Design Lab:

> *I just hate the fact that we get no technical knowledge from this class. Both of our instructors are very non-technical. I don't hate the fact that they are non-technical. I just, for a design class that's supposed to mix design with the ability to actually carry out a design, to not have instructors who give you any feedback on how to carry out the design, makes it so difficult for me.*

Another student expanded on this concern, explaining:

> *I think the biggest problem I've been facing with my project is that it's very out of our element. Without a technical teacher to really guide us, we keep being encouraged to come up with more ideas of how to make it more of a critical design, add this, add this, add this. The more we add, I'm realizing the less that this is actually applicable. Or the less that we can actually simulate or create a prototype for because this is so far out of our range we probably can't even do half the stuff we talk about doing. It's getting*

difficult to keep up. We're encouraged to keep coming up with ideas but we don't have a teacher with technical skills to say, "Hold on. Can you actually do this?"

Unifying Liberal Education and Technology into a Single Experience (Fall 2016-Spring 2017)

The concern about students' lack of respect for—or understanding of—humanities-related topics and, in some cases, an unwillingness to read about or engage with such topics, was a core concern that we had not been able to resolve over the previous two years. While instructors with humanities backgrounds continued to express their feeling that their contribution was minimized, others suggested that perhaps Seminar instructors were not sufficiently empathizing with students or meeting them "where they are at." For example, students had a hostile reaction to readings on feminist technology in Fall 2015, possibly due to the inaccessibility of the content to the generally conservative, nearly all-male student group. This lack of accessibility (or lack of ability to enter another worldview that was seen as hostile to one's own) made any transfer of concepts to their Design Lab project unlikely. Seminar instructors, in turn, argued that once again the humanities approach was being minimized and made "in service to" design work. This discussion revealed that 1) we, as a faculty, did not have a common foundation to the degree as originally thought; and 2) this technology-focused group of students not only saw faculty as being aligned with specific disciplines (either technical or "not"), but also failed to see the courses as connected, even when we as faculty did.

The fellows felt the time had come to demonstrate more directly that concepts relating to liberal education were not less important or less relevant to their future goals, and that there is not a true barrier between what might be covered in a class called Seminar and what might be covered in a class called Design Lab. Therefore, starting in Fall 2016, we merged the two courses into one learning experience called *Studio*, an integrated experience intended to continuously bridge and synthesize knowledge from across the humanities with technical content in a single project-based curriculum. From the beginning of the semester, instructors noticed both positive changes and some frustrating lack of change among the students. One instructor noted his satisfaction with students' responses to readings, including works of fiction, such as "Flowers for Algernon" by Daniel Keyes. As this instructor explained, his goals for these readings did not align with specific technical or non-technical skill development, or with any particular project:

There's no boundary […] on what we would hope they get out of them. As stated, thematically, they're two books that uniquely deal with the human-machine interaction that our course revolves around. Specifically, the themes included range from everything from dystopian studies to sexuality to technology as a handicap to technology as a tool against/weapon for societal inequality, etc. Ideally, a literary analysis will cross an unspecified number of things to create a larger thread of discussion.

He felt that some of the changes witnessed during the Fall 2016 semester may have been due to maturity, but gave a lot of credit to *"establishment of reading as something of a 'norm',"* which was in part achieved through requiring reading responses for the last two years across the learning experiences. He also felt that the previous distinction of "*seminar (and reading) as a 'separate' thing from tech [...] fed into an aversion that [students] carried into the program of making this not tech/not relevant stuff,*" and he expressed hope that in the future, having a single, merged experience would allow students to more naturally begin to see connections between

things, and "*excitedly ask 'how can I connect these two things' rather than doubtfully ask 'how are these things connected.*"

One student especially appreciated the theme, which helped to link human interactions with technology that could be produced.

> *I like the humanities side of this class a lot because it's human interaction and cyber technology. You have to be able to understand from a humanities standpoint [...] To understand the users so you can design stuff that are useful to them...You just understand that this thing you designed for this user will have a huge impact on his personal life, social life, his dating life, his everything. [...] You just realize that you have this empathy, you have this all emotions. That's what drives you to design better products for other people. [...] To be able to understand, it's so important. I love it.*

However, the instructors felt that students were uneven in their reception and application of disciplinary perspectives—even among skills that could be seen as a natural part of a design process, but might not be seen as direct technical skills. As one instructor exclaimed, *"They're amazing with some of the reading stuff, and some of the connections they're making, and then some of the other times it's just like, really?"* She went on to describe her frustration with some of the students' self-proclaimed inability to locate and interview users in target groups for their projects, as well as lack of use of techniques to engage with embodied cognition such as bodystorming—skills that several students deemed to be non-technical and thus of little value. As this instructor explained, some students *"are still very much at the 'this is what I want to build stage.'"* She went on to describe a student project that involved building a recreational vehicle for individuals with limited mobility, who *"can't seem to get himself to a point where he can see if he can find that population,"* and recounted occasions when she thought, *"Oh, I so want to put him in [a] wheelchair, and tie his legs together so he can't use them, and then have him get in a rail buggy."*

However, some students found the unified course experience to be a valuable opportunity for growth. One student compared early projects to their later project:

> *If you've got this tracker that works great, apply the things you learned from it and apply the prototype that you have to a disability, and it's like, "Well, okay, but can they even use it?" Now you're going to a different route saying, "What is this group can do with this to make it benefit them?" It's like it's entirely applied technology to a group of people, more so than just applying technology to a problem…. [The non-technical content] drives the project a lot more than hinders it.*

At least one student identified the role of his own maturity level in breaking through the barriers he and his peers had experienced in previous years.

> *I just think it should be rephrased differently. […] I like the point of the early [projects] because I thought it was breaking down our dumb cognitive barriers and now, since we're in the junior year, we're actually starting to understand all these other problems that we had. […] we have those ideas of that we don't know everything so we put the*

> *concepts of the previous semesters into projects that we can more understand to make them more whole where can't find all the holes.*

Another student was pleased to find that the humanities content was more applied this semester, noting: *"I feel like often humanities is pointless […] because often it is left in the abstract and not applied, and this semester, I'm kind of happy because it's been applied."* This student explained further that he did not value

> *just talking about talking about thinking […] and there's no doing; and the whole premise of the program in the first place is supposed to be doing while learning and learning while doing […]. This semester is very clear and upfront and I think what that does is it applies something that, unless it applied, it's pointless.*

In contrast to this viewpoint of humanities content only having value when it is "applied," another student reflected on the oft-mentioned sense of the content having been "blurred", and how such blurring could be beneficial.

> *I can't give you a specific example because that's just the nature of doing the whole thing, of combining technical and non-technical. It becomes very blurred because it all becomes one unique gaseous entity, because then you can go between the two without even realizing you are. It becomes second nature at that point […].*

In a later interview, this student indicated that he was beginning to see how things he learned from outside courses informed his understanding of materials and project work—even sharing information from outside courses with his peers at appropriate points.

> *A lot of stuff that we would talk about… I would get an essence of from my other classes. Little bits I would learn from my psychology courses. Little bits I would learn from my [educational psychology] course. I would see them come into the readings. I would see them come into my design process. I would see them in the points that [the instructors] were trying to push towards us... My abnormal psychology, they talked about how people seeing different things, we talked about PTSD a lot, and how simply going through the motions or having VR is very helpful, why [a fellow student] might benefit from VR application with learning or something like that.*

Discussion

In this case study, we have demonstrated our approach to systematically integrating liberal education and technology perspectives in three different ways—moving from combining existing courses into a larger experience to creating parallel course experiences that embody different pedagogical and disciplinary perspectives to a unified course experience that develops transdisciplinary ability from within. In each instructional approach, we have identified barriers to implementation, both on the program and faculty level, and in the reception of our instructional goals by students. This case is instructive in understanding institutional, faculty, and student barriers to integrating technology and liberal education, allowing greater awareness of how course experiences should be designed and staffed. In addition, our multiple approaches to

incorporating liberal education content demonstrate the risk of unintentionally "colonizing" the humanities, placing liberal education primarily "in service" of technological aims.

Barriers to the Systematic Integration of Liberal Education and Technology

The obstacles to closing the divide between historically siloed disciplines can be observed at multiple levels. On an *institutional level*, it was difficult to recruit individuals, and even harder to create lasting partnerships, to form our transdisciplinary team. Concerns over a declining enrollment in traditional liberal education courses created roadblocks to our initial plans to integrate such experiences fully within our own transdisciplinary courses. Furthermore, scheduling and staffing our non-traditional course experiences created unexpected hurdles at the college and university level, which reveals fundamental challenges in building innovative learning environments.[38,41]

The divide between technology and liberal education can easily be observed on the *faculty level,* even within the design and teaching team. Across multiple semesters, instructors from liberal education disciplines felt that what they had to offer was perceived by other faculty and students to be of lesser importance than technical topics and skill development, and that the humanities-oriented Seminar was undervalued compared to the studio-based Design Lab course. Indeed, while the program was intended to be transdisciplinary it was still housed in a technology-focused College, further enhancing the feeling that, even if liberal arts faculty were included, they were working "in service of" technological disciplines rather than being equally valued in a program that aimed for true transdisciplinarity. Another potential reason for this reaction among faculty relates to concerns about how humanities skills and knowledge are gained and assessed. It was clear that concrete, technical skills could be gained in skill-targeted experiences that may be chunked and assessed in multiple, relatively easy to define ways. In contrast, the development of soft skills requires ongoing exposure and acquisition across multiple course and non-course experiences,[42] which may create a somewhat subconscious assumption that the focus should be on the STEM-courses, while humanities can be more on a "situational" learning level (e.g., [43]). Challenges in finding a common language were complicated by a lack of shared understanding regarding pedagogical approaches and instructional methods commonly used in their domains.

On a *student level*, we observed two trends. Students continued to see what they deemed as technical skills to be different in nature from liberal education topics, and perceived exploration of liberal education topics as being of lesser interest or import than "building stuff." While students appear to be more receptive to these concerns after five semesters, the relative weight they give to direct application of technical skills over activities such as reading, reflection, and discussion on topics with no obvious correct answer is still evident. The reticence of students to involve users in their design process, even as data sources, appears to be linked in some students' minds to a lack of importance of 'fluffy' or 'soft' skills; this also appears to stem from a lack of understanding that different individuals can have fundamentally different needs or desires, a recurring topic in both the Seminar and Design Lab courses. While the importance of professional skills, such as communications and teamwork, are generally acknowledged as being important in the workplace and have been encouraged within engineering education in recent years (e.g., [42]), less tangible skills and 'lenses' typically introduced as part of a "well-rounded" liberal education are often not as easily linked to application in a student's imagined technical career. This felt lack of direct application may have been particularly true among our first student

group. Limited recruitment opportunities for our pilot group, attracted a number of students who were particularly interested in our program's promise of hands-on and project-based experiences, and failed to attract or retain students who identified themselves as being more interested in humanities than technology. As a result, students' individual expectations may have clashed with the transdisciplinary ideals of the program.

In addition, students seemed to perceive each faculty member as merely representative of a single discipline, although all faculty members in the program had unique cross-disciplinary backgrounds and interests. Multiple factors may have played into the students' tendency to put instructors into disciplinary "boxes," and to have different expectations across faculty members that did not align with how faculty saw themselves. In part this may be explained by the focus on a specific discipline during initial introductions of the multi-disciplinary faculty, or the role they served within the students' initial experiences. Gender may have also played a role, in that more technologically-intensive questions were addressed to male instructors, which would be consistent with literature on perception of traditional gender stereotypes in a STEM environment (e.g., [44,45]). This differentiation of faculty is both a symptom of, and a potential reason for, students' difficulties in seeing themselves as fully transdisciplinary.

Consolidating or Colonizing? Bridging the Developmental Divide

In the experiences we have discussed, there was a constant tension between fully integrating liberal education perspectives and using liberal education to support technological aims. While other scholars have addressed this tension to varying degrees (e.g., [2,15]), the concern of unintentionally "colonizing" content and concepts from liberal education domains was a continual source of conversation among the program fellows. Through our collective efforts to mark out a specific set of pedagogical and instructional constraints for the combined course experience, we often had to address whether this consolidation would further disenfranchise liberal education perspectives, rather than providing the equal footing that we desired. We present the concern of consolidating v. colonizing liberal education as a continuing source of instructional tension, which may reflect broader issues relating to embracing the humanistic dimensions of engineering education and praxis.

The tensions we felt in relation to emphasizing certain perspectives on student projects and in classroom instruction also relate strongly to the needs of employers and the recognition of transfer among disciplinary perspectives that students can account for and apply in their work. With the shift towards globalized commercial competition, technological advances, corporate downsizing, and other economically and technologically driven tendencies, employers emphasize the need for competencies in professional skills and forces that may impact design, engineering, and production (John Prados, 1991-92 ABET president, as cited in [42]). As such, students need to not only develop deep understanding of individual disciplines on their own terms and be able to transfer their knowledge across contexts and even disciplines, or from the known to "the unknown;"[46] but, they must also be able to synthesize their knowledge across domains to create a unique intellectual transdisciplinary framework[47] that may inform creative and innovative solutions to "wicked" problems.

However, to achieve this level of transdisciplinary thinking and acting, students first need to be able to engage in higher level transfer beyond automatic, well-practiced behaviors.[31] Indeed, this level of transfer from liberal education perspectives toward their design projects was quite

challenging. We have observed that students were not comfortable with issues that were harder for them to relate or actively empathize with, such as identifying what vegetables would be the most important for a low-income family to grow in a garden-in-the box in their Fall 2014 group projects. Some students focused on what vegetables grew faster, but with little attention to nutritional value; while others looked at vegetables that were perceived to be fancier and healthy (e.g., asparagus) without taking into consideration the time it would take to grow the crops. When presenting their decisions on this and other topics related to the design, student groups rarely talked about what such decisions really meant to their hypothetical family of four, co-residing with the garden in a limited space and, presumably, relying on this garden for daily meals to be produced in this same setting. In Fall 2015, students were asked to create solutions to resolve issues of sanitation and hygiene in specific third world settings. Although students conducted research on their target countries' populations, the problems they discussed when presenting their final solutions were often reductionist, not appearing to address the full breadth of problems presented in the target cultures and geography. Additionally, the differences of individuals within a population (e.g., gender, age) were hardly touched on, despite repeated probes by instructors throughout the semester. Although in the current semester, these students have shown greater understanding of the importance of considering user needs, their reticence to collect data from actual target users indicates that they are still uncomfortable with the concept of interacting with, and gaining different perspectives from, people different from themselves.

Based on these experiences with students, we agree with Walther et al.[16] that empathy may be a core "soft skill" that enables cross-disciplinary transfer to occur. More research is needed to understand how empathy may enable or serve as a precursor to transdisciplinary thinking and acting. To support students in developing metacognitive processes such as empathy and higher level transfer, we included written reflection activities both in the Seminar and Design Lab since Spring of 2016. These activities were continued in the combined Studio environment, and were intended to encourage students to process, internalize, and apply what they had learned to their immediate projects. But as noted in our findings, we also learned that a substantial number of our students had a strong dislike towards reading and writing, and as a result, some of them tended to provide a minimal reflection or skip the assignment altogether. This precipitated the introduction of in-class discussions that aligned with the reflective questions used to supplement and support their development of higher level transfer. While these activities have allowed students to develop their abilities, we continue to identify additional activities that may increase students' development of transdisciplinary ability.

Limitations & Areas of Future Research

Due to the inherent limitations of case study research, the findings we presented may not be generalizable to other settings. However, those attempting to develop similar programs or integrate similar components into existing programs may find themselves confronting similar challenges. Due to the relatively small number of faculty and students engaged in the program thus far, we cannot provide additional demographic information without risk to participant anonymity. Although we cannot provide specific numbers, the number of female students is characteristically low (similar in proportion to many engineering and technology programs). The program is expected to grow over the next several years, allowing for collection of data from a larger number of students and the use of quantitative as well as qualitative data sources. We also anticipate the composition of students in the program may shift, attracting more students who are

interested in a truly transdisciplinary program. In contrast, the pilot group was recruited out of traditional technology disciplines and may have been drawn more to the hands-on, project-based aspects of the program than to the integration of humanities within a transdisciplinary model.

As we look to future work, we anticipate expanding upon the case study approach taken here to engage in further meaning reconstruction work (Phase 2 of Carspecken's[36] critical ethnographic approach) to more deeply understand the barriers to transdisciplinary learning and liberal education perspectives that our students may have experienced. As new students matriculate into the program, we also expect to be able to compare meaning reconstruction and dialogical data generation among the student populations and identify additional barriers based on student motivations and expectations.

Conclusion

In this paper, we have identified multiple approaches to systematically integrating liberal education and technology in an innovative, transdisciplinary program. As engineering educators further incorporate aspects of humanistic engineering into their course experiences, we expect that these aspects of systematic integration offer important considerations. During this integration process, we have encountered a number of obstacles to realizing a truly transdisciplinary program that gives equal voice to multiple disciplinary perspectives, including the necessity of faculty alignment and instructional planning. Our findings indicate the need to focus on the enculturation of a transdisciplinary mindset from the recruitment phase, giving equal time and effort to instilling disciplinary knowledge from a multiplicity of perspectives, and encouraging students to understand the faculty as multi-dimensional and transdisciplinary in their own unique ways.

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