A R T I C L E

Connectivity, Expectations, and Expertise: Co-creation as a Model for Program Development

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Abstract. Working with industry stakeholders to design programs in technical, scientific, and professional communication can provoke discussions about the connectivity, expectations, and varying expertise(s) at work in the collaboration. Co-creation models for program development can mitigate these challenges by using program design and assessment practices that depend on stakeholder contributions throughout the curriculum. This article explores an example of the co-creation model at work in designing a project-based, studio-centered curriculum.
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How can technical communicators engage industry stakeholders within the development and implementation of a transdisciplinary program? To answer this question, we consider challenges faced and solutions acquired through the implementation of a co-creation model of program design between 75 industry partners and 27 faculty at a large polytechnic university. Created through a $20 million donation (Polikoff, 2018a) to develop a model of higher education that emphasizes "high-impact technology innovation that advances society" (Polikoff, 2018b, para. 3) the program, based in the university's honors college, teaches students to collabo-

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rate across disciplines and sectors to understand multiple perspectives to complex problems (Polikoff, 2018b). The program currently enrolls students in 18 major programs[1] , including English, communication, business, and engineering. Industry and nonprofit partners include stakeholders from the Boeing Company, General Electric, Caterpillar, the Association for Financial Professionals, the Capital Youth Empowerment Program, and Ithaka S+R.

Each semester, students in the program enroll in a project-based, studio course, where they work with students and faculty from multiple disciplines and industry partners from multiple sectors to research complex problems and prototype solutions. As examples, the program's teams have developed prototypes for measuring cognitive overload, created adaptive learning paths for underserved communities to access higher education, and designed robots to alleviate the risk of injury for factory workers. In addition to studio classes, students enroll in specialized coursework that teaches the skills that they need to collaborate and communicate across disciplines, manage projects, and prototype technologies. These courses include six credits of technical and professional communication coursework, as well as coursework in humanities, coding, and business management. The program has many stakeholders; we use the co-creation model to encourage their engagement in the program; to navigate expectations from students, faculty, and industry partners about the value of transdisciplinary education; and to recognize the different kinds of expertise at work within the program's projects and courses.

Industry-academic partnerships enrich student experience by providing mentorship opportunities and aiding transfer from classroom instruction to professional development. However, as scholarship in technical communication has noted, balancing these collaborations can be difficult. As Jennifer Bay, Richard Johnson-Sheehan, and Devon Cook (2018) acknowledged, maintaining connections with industry partners over time can be challenging (p. 190). Extending from this scholarship, we needed a model for program development to foreground the ideas of industry partners within the curriculum, with an eye toward encouraging their long-term engagement in the program. Another prescient concern from technical communication

[1] Current majors in the program are Cybersecurity Management and Analytics; Business Information Technology; Entrepreneurship, Innovation, & Technology Management; Human Resource Management; Management, Management Consulting and Analytics; Computer Engineering; Electrical Engineering; Industrial Systems Engineering; Communication; Multimedia Journalism; Public Relations; Computational Modeling and Data Analytics; Creative Technologies; Graphic Design; English Literature; Environmental Policy & Planning; Smart & Sustainable Cities; and Industrial Design.

scholarshipis the potential for unexamined focus on industry; in their commentary on dynamic program design, Kathleen Coffey, Angela Glotfelter, and Michele Simmons (2020) cautioned teachers and scholars to be "responsive" rather than "reactive" to external pressures, such as the demand for student workplace readiness (p. 139). Indeed, most of the program's media coverage focuses on its involvement with industry. For example, in an article appearing in *The Wall Street Journal*, the program was referenced as part of a "crusade to churn out more competent thinkers at a younger age" (Stoll, 2020). This article and other media coverage may lead to stakeholder perceptions that the program exists merely as a feeder program—a pipeline from education to employment with our industry partners. We needed our model of program development to address these varying expectations of workplace readiness as well.

We use the term "co-creation" to describe our method of program development because it implies that all stakeholders share responsibility for keeping the program running—now and in the future. Co-creation is a lofty goal that requires constant dialogue about what those responsibilities look like at any given moment. We anchor our co-creation model with procedures for stakeholder input and goals for program growth. As with other models of education for societal impact, including service learning (Bourelle, 2014), community-based participatory research (Brock Carlson, 2020), and the transformative paradigm for socially-just work (Phelps, 2020), co-creation facilitates knowledge production between researchers and practitioners when they work with various community stakeholders. We use the co-creation model to design a model for transdisciplinary education that enables sociotechnical innovation.

Transdisciplinary education and sociotechnical innovation are even loftier goals than co-creation. For us, "transdisciplinary" means that students are prepared to move throughout different disciplinary schools of thought to solve a given problem. Students majoring in liberal arts and human sciences take coursework in prototyping and developing business plans, whereas students majoring in engineering and business take coursework in environmental sustainability and societal inequalities. We use the term "transdisciplinary" in alignment with feedback from industry partners who have criticized the disciplinary boundaries of the contemporary university. One program stakeholder noted in *The Wall Street Journal* that colleges are not "teaching how to think outside the cubicle or beyond the screen in front of them" (Stoll, 2020). Dividing students into major-based skillsets impacts their ability to lead programs and projects, creating a "discovery gap" that employers have to mitigate. Without the ability to think across sectors and disciplines, individuals are unable achieve sociotechnical innovation.

Sociotechnical innovation refers to solutions or prototypes that involve both societal and technical interventions to solve wicked problems ("wicked problems" originally used in Rittel & Webber, 1973). For instance, the student team that designed robotic elements to alleviate the risk of repetitive motion injuries for factory workers includes updated training and workplace policies alongside the technical fix. Students learn that sociotechnical innovation is an approach that "[considers] financial viability and technological feasibility, ecological and socioeconomic sustainability, and inclusive human capital development," according to one of the program's industry partners (Association for Financial Professionals, 2021). The program's industry partners and faculty mentors help students navigate these conflicting demands of industry-motivated outcome areas, emphasis on technological innovation, and focus on societal impact.

In this article, we detail the development and assessment of our co-creation model with 3 years of programmatic data, including internship placement data and student experiences. As students and industry partners collaborate to determine sociotechnical solutions to complex problems, faculty provide concurrent instruction in project management, technical know-how, professional writing, and presentation and interface design. Students transfer these skills directly into projects during their first year and further develop these skills within the program's studio and capstone courses. Working with students who can communicate and collaborate across disciplines, industry stakeholders envision new opportunities for recruitment and leadership within their companies. By integrating faculty, students, and industry partners within the co-creation model, this article details how technical communicators can synthesize stakeholder connectivity, expectations, and expertise to design and sustain transdisciplinary programs.

Literature Review

This article's development of a co-creation model for engagement of program stakeholders aligns with scholarship in technical communication, particularly research in project-based learning and industry-academic partnerships. This literature review connects our project with research on involving stakeholders within student course projects and programmatic partnerships. We then touch on some of the industry-motivated and institutional forces our program is in conversation with, like point-of-need learning (PNL) and micro-credentialling solutions to advance transdisciplinary education. As we navigate these stakeholder-given specifications for the program, we find ourselves drawing on this scholarship to shape the co-creation model to better integrate stakeholders within the program and its curriculum.

Project-based learning that asks students to work in groups to complete written or multimodal deliverables is common within technical communication pedagogy. As the Technical and Professional Communication Community of Practice (n.d.) noted, common deliverables taught within technical communication include resumes, reports, proposals, information design projects, instructions, and other research projects. Project-based curricula provide a focus for these genres and aid student learning about workplace writing, project management, and tools for successful collaboration. However, some scholars have called attention to the need for innovation in technical communication coursework. For example, Bay et al. (2018) asserted that "students in technical communication service courses need to be taught how to think like entrepreneurs, which means mastering creative processes that propel innovation in the entrepreneurial workplace" (p. 172). As the authors noted, engaging in design thinking practices helps technical communication grow beyond traditional, transactional genres of writing. Entrepreneurial education emphasizes the "invented" genre, contrasted to "standard business genres" (p. 173). These "standard" genres also may cause tension between perceptions of technical communication pedagogy, like teaching students to write clearly, and goals of technical communication as a field. As Laura Gonzales, Kendall Leon, and Ann Shivers-McNair (2020) noted, technical communication pedagogy has "a long way to go to adequately support students' diverse communicative practices, cultural and racial experiences and expertise, and embodied histories" (p. 68). Accordingly, when designing curricula, technical communicators need to balance stakeholder specifications for coursework alongside the field's pursuit of social change.

In addition to genre innovation, industry partnerships can add to program visibility both inside and outside the institution. Lora Arduser (2018) examined how technical communication scholarship has been concerned with disciplinary power and legitimacy in relation to industry (p. 15). The more connections that a program is able to make, the more visible it is within the community. In context, visibility can lead to additional partnerships with industry and additional sociotechnical problems for students to consider. As Steven Fraiberg (2021) wrote in his introduction to a special issue on innovation and entrepreneurship communication in a global context, "entrepreneurial clusters" intersectwith higher education as universities collaborate with communities and industry partners at both local and global levels (p. 176). Given technical communication's facility with networked systems, scholars are "solidly positioned" to explore how entrepreneurial collaboratives are situated within rhetorical practices (p. 177). Presented in this way, industry partnerships provide contributions beyond student experience and the opportunity for programmatic improvement.

Alongside other technical communication scholars who caution against industry involvement as a quick solution to a program's need for innovative curricula, or workplace preparedness, we want to briefly note some concerns with industry collaboration. In 2006, Emily Thrush and Linda Hooper asked questions made pertinent given the emphasis on efficiency in higher education:

Have we kept up with trends and needs in the industry for which we are preparing our students? How do we keep our own skills up-to-date, keep our courses relevant to our students' needs, and prepare professionals with the flexibility required by the rapidly changing world of professional writing? (p. 308)

For Thrush and Hooper (2006), the answers resided in team-teaching opportunities at the course level and frequent collaboration between students and industry partners. The move is a common one though; given student feedback about working with industry partners, team teaching with industry partners does not automatically bring innovation to the curriculum.

As well, when collaborating with industry partners, partners may be tempted to think about academia and industry as opposites: one based in theory and one in practice. Ann Marie Francis (2018) examined this perceived divide between classroom projects and industry writing based on studies in technical communication. Scholars articulate the need to cross over the perceived academic-industry divide, often for programmatic benefit. As Chris Eisenhart and Karen Gulbrandsen (2020) commented, creating curricula that connect theory and practice in alignment with expectations from students and industry is a trend in the field, resulting in more flexible options for degree-holders (p. 82) The addition of industry partnership, however, does not automatically yield more engaging, transferable educational experiences. Elisabeth Kramer-Simpson (2016) explored models of industry mentorship of student interns, finding that most industry mentors "…rarely build in supports in the design of the project. Rather, they at-the-moment assess student understanding through frequent face-to-face meetings and provide feedback and guidance..." (p. 83). In context, students often express confusion that industry partners do not have all the answers, nor can those industry partners express definitively what the project team should do to get a good grade on the deliverable. Industry partners provide students with one perspective toward sociotechnical innovation. Just as students are encouraged to find additional stakeholders to provide perspectives on prototypes, technical communicators should rely on additional stakeholders when building programs.

In keeping with our program's emphasis on transdisciplinary education and sociotechnical innovation, we collaborate with our own stakeholder to envision what workplaces and work practices might look like in the future and which educational models might best facilitate the future of work. Conceptualizing the future of work in this way also has led us to incorporate perspectives on PNL and micro-credentialling, both practices of building lifelong learning into the workplace. These practices have allowed us to design a transdisciplinary curriculum that insists that all students learn the fundamentals of technical communication, graphic design, programming languages, and program management. In the following section, we elaborate on the methods we use to integrate these transdisciplinary pathways within the program's design.

Method

In this section, we discuss using the co-creation model as a methodology for program design and assessment. We used multiple methods to design, deploy, and assess this model of program design: focus groups of different stakeholders, questionnaires of students at different points during the program, semi-structured group discussions of students and faculty, and observations from participating faculty and industry partners on the model's effectiveness. We also include relevant program deliverables in our analysis, including student projects, internship and other placement data, and other curriculum information. We choose these multiple methods because, at any given point, the program includes approximately 250 stakeholders; we require feasible and sustainable means of collecting and analyzing perspectives from all participants[2].

[2] From 2018 to 2021, programmatic data were collected by the university's Center for Higher Education Innovation. These data were considered to be program assessment and were exempted from further review by the university's institutional review board.

Technical Communication and Program Assessment Methods

The methods we employ in this study are not unknown within technical communication scholarship. Focus groups, surveys or questionnaires, and collecting program deliverables are common ways of including voices of stakeholders within programs as well as assessing program outcomes. For example, in Chris Dayley's (2021) article on student-informed practices for recruiting diverse students, the author encouraged the use of advisory groups and surveys, among other communication methods (p. 33). Meanwhile, Henry Covey, Jordana Bowen, and Sarah Read (2021) noted that "focus groups, surveys, and interviews with individuals" are "information gathering methodologies for UX" (p. 125). In Scott J. Kowalewski and Bill Williamson's 2016 program showcase, the authors included "focus groups, questionnaires, exit interviews, and in-class reflections" to include student voices in programmatic change (p. 114). Moreover, Sweta Baniya, Ashley Brein, and Kylie Call (2021) analyzed student reflection videos to determine student experience and perceptions of growth (p. 34). We use these methods to codify the shared responsibility of our many stakeholders in creating our program. As aforementioned, co-creation is a lofty goal and a model for program design that is difficult to enact. Using focus groups, questionnaires, and semi-structured discussions to create pathways for the inclusion of stakeholder perspectives is one way to show stakeholders that their input is necessary for the program's continued existence.

The Data Collection Cycle

We built data collection into the program's yearly operation through events for students, faculty, and industry partners. Industry-partner focus groups take place through orientation and student exposition days, and faculty/student semi-structured group discussions are held at the conclusion of each academic year. Student questionnaires are distributed shortly after exposition days, giving us six data collection points per year. We describe these data-collection methods and choice of student deliverables for assessment below.

Industry partner focus groups. Perspectives from industry partners are imbricated within the program through focus groups deployed at three points each academic year: the industry partner orientation, an exposition day (Expo) at the end of the fall semester, and a final Expo at the end of the spring semester/academic year. During each of these all-day events, industry partners, in conversation with faculty, categorize sociotechnical problems that they foresee in their organizations into broader outcome areas. These outcome areas provide organization for students and thematic focus for the program in the following year. As well, industry partners also provide feedback on PNL modules with which students should engage to learn more about the outcome areas. (Table 1 shows how outcome areas help group sociotechnical problems.)

Table 1. How industry-provided outcome areas help group sociotechnical problems and structure means of proposing projects

Outcome Area	Sociotechnical Problems within Outcome Area
Innovation and Society	Adapting educational technologies for prisons; providing energy to power internet access and educational technology for energy-insecure households in the county
Product/Platform Capabilities	Proving inclusive clothing size options through supply-chain management and interface design
Advanced Manufacturing	Reducing physical stressors on workers through robotics and augmented reality; preparing lunar surface for excavation and habitation

Faculty/Student semi-structured group discussions. Once industry partners choose outcome areas, faculty and students participate in an open forum to co-create ideas about which sociotechnical problems teams might address in the coming academic year. To co-create ideas, students learn about outcome areas and produce multimodal project pitches that include problem space, solution concept, and potential industry partner. Students vote on their preferred projects and teams are formed for the coming year. (Table 2 shows how outcome areas define sociotechnical problems, which, in turn, lead to transdisciplinary project teams.)

To assess programmatic outcomes of transdisciplinary education and sociotechnical innovation, we focus on collecting student deliverables related to project-development milestones. Project-development milestones help us cohere to the standard 15-week academic semester while still showing students that industry-motivated projects often take years to complete. Project-development milestones, borrowed from the NASA Program/Project Life Cycle (National Aeronautics and Space Administration, 2019), provide timely touchpoints for students during the semester while still moving the project forward into the next semester and academic year. Deliverables associated with project-development milestones include multimodal presentations, stakeholder interviews or site visits, risk assessments, business plans, and prototypes. Although students deliver project-development milestones each year, expectations for the items associated with each milestone increase as the students move through the program.

Table 2. Exploring how outcome areas define sociotechnical problems and lead to transdisciplinary project teams

Outcome Area	Sociotechnical Problems within Outcome Area	Distribution of Academic Majors on Sample Teams
Innovation and Society	Adapting educational technologies for prisons	Communication, Industrial Design, Computational Modeling and Data Analytics, Management, Business Information Technology
Product/Platform Capabilities	Proving inclusive clothing size options through supply-chain management and interface design	Business Information Technology, Industrial Design, Industrial and Systems Engineering
Advanced Manufacturing	Reducing physical stressors on workers through robotics and augmented reality	Architecture, Electrical Engineering, Computational Modeling and Data Analytics, Industrial and Systems Engineering, Business Information Technology

Questionnaires. In addition to motivating student-produced deliverables, project-development milestones also provide an inroad for assessing student and industry partner perceptions of the program, co-creation model, and collaboration efforts for all program stakeholders. At the conclusion of each milestone, students and industry partners complete separate questionnaires about the program, projects, and student experience. These results help us assess current projects and industry perceptions of student learning.

Student questionnaires focus on experience working on the project, experience working in groups, transdisciplinary learning (or what skills outside their discipline they have employed in the project), and experience with specific industry partners. Industry-partner questionnaires assess how effective project teams are at analyzing the sociotechnical problem space, proposing an innovative and socially impactful solution, employing design concepts, describing risks, issues, and mitigation plans, articulating a business plan, and formulating realistic project outcomes and a completion plan. With team deliverables, questionnaires provide student and industry-partner perspectives on the capacity of the co-creation model to address collaborative sociotechnical innovation.

Results

Going into its fourth year, our co-creation model has resulted in programmatic growth. We measure programmatic growth by the number of industry partners and inclusion of new major programs. In three years, the program has gone from 3 to 75 industry partners ("Calhoun Discovery Program," 2018). Additionally, the industrial sectors from which these partners hail have become more diverse. Three years ago, industry partners were mostly engineers, but with the recruitment of new partners from nonprofit, business, and governmental sectors, professors of practice can now provide expertise in business plans and marketing, data analytics and machine learning, and educational technology for workforce development, among other areas. The ideas that these industry partners contribute to programmatic discussions have resulted in additional outcome areas for the program and new opportunities for students. As well, when industry partners from multiple companies and sectors serve as mentors on a team, all members are better able to understand how disciplinary silos have constrained the workforce and how transdisciplinary project teams might transform work environments.

The program also draws students from a larger number of major programs, from 12 majors in 2019 to 18 majors going into the 2022–2023 academic year.

The work of forming course substitution agreements with admissions specialists and advisors is a separate logistical feat, but the increase stands as evidence of other academic programs' support of the learning experience offered by our program. Despite multiple course substitutions each year for students to take project-based courses through our program instead of through their home departments, only one academic program has objected to the loss of student credit hours. As an additional sign of support from affiliate academic programs, many admissions specialists present the program to students as an alternative opportunity to traditional coursework, leading to increased numbers of students expressing interest in the program and completing admissions interviews[3].

Transdisciplinary Education and Sociotechnical Innovation

We examine transdisciplinary education and sociotechnical innovation facilitated by the co-creation model by analyzing how students have adjusted to the educational experience offered by the program, parsing student internship data and collecting student deliverables related to project-development milestones. Results from student-experience data and internship-placement numbers speak well for the value of the transdisciplinary learning experience. Deliverables from project-development milestones suggest that student teams understand the value of sociotechnical innovation based on the increasing numbers of high-fidelity prototypes produced. However, industry partner and faculty observations of prototypes have noted the need for increased innovation in student projects.

Student questionnaires taken from each cohort indicate that students are learning skills from outside their home majors in the program, which bodes well for our programmatic focus on transdisciplinary education. Although numerical satisfaction scores remain consistent across cohorts, with students rating their experience in the program as 3.8/5 on average, qualitative data about student experience show increased transdisciplinary skills learned. (Table 3 shows how students in different cohorts responded to this prompt.) Although students in the 2020 cohort report gaining research, interviewing, and presentation skills, students in the 2021 cohort report gaining more specific transdisciplinary skills like coding, using Arduinos, learning new software, and writing business plans. The shift may indicate efficacy of the co-creation model at promoting transdisciplinary capabilities in students.

Internship-placement data, in conjunction with observations of student professional development, also aid our claim that the transdisciplinary education promoted by the program impacts student success. In summer 2021, 76% (28/37 second-year students) and 38% (14/37 first-year students) received summer[4] internships or fellowships at companies including Deloitte, Noblis, Verizon, Aurora Flight Sciences, Spectrum, Intel, the Environmental Protection Agency, the Naval Research Laboratory, Dell, and General Electric. Although we will not have data on our graduating students until 2023, data already report a higher percentage of second-year students in internships than the

[3] As the program is still in its pilot, student enrollment is capped, so we do not use enrollment data to examine programmatic growth.

[4] Though we encourage students to seek out paid internships, students in the program receive a $2500 stipend each year to use toward experiential learning, including room and board costs during summer internships.

Table 3. Differences between skills reportedly learned in different cohorts may show evidence of transdisciplinary thinking (Source: Optional question on student-experience questionnaire provided to each cohort at the end of the first year in the program)

First-year Students in 2020 Cohort	First-year Students in 2021 Cohort
In this phase I really learned the importance of scale.	I never knew how to code or what that looked like which I learned.
How to access risks a solution may have.	I learned how to use an Arduino and write a business plan
How to develop a significant project in the private sector	Fusion 360 and CAD in general.
Learning how to research effectively, improve my quality of work	I learned a lot from my peers on designing through CAD as well as animations.
I had to do a lot of research so I could understand the subject matter of my project, but I really liked in the interviews learning about the different policies and obstacles our industry partners faced.	collaboration, making a pitch, business model, prototyping
I improved my recorded presentation skills, I learned a lot about supply chains, and I learned how to work with new types of people. I also learned more about the system viewpoints.	I learned more about technical skills that I had never used before.
I learned about industry 3D printers, about the business aspect of contracts and regulations industry has to follow, and how to get a lot of work done in a little bit of time	I learned a lot about being a teammate instead of a leader. I had to actually compromise and people didn't blindly listen to me. I learned a lot more about effective design when it came to our presentation and expo materials, and I feel I honestly gained way more than my traditional track peers, because I feel I didn't learn or gain near as much from my other classes combined as I did in studio.

national average of graduating seniors (60%, according to the National Association of Colleges and Employers, 2017). Combined with observations of student professional development from both faculty and industry partners, the program seems to provide students with the experiences that they need to be competitive in obtaining internships. Students report, for example, that when interviewers see transdisciplinary, project-based learning on their resumes, the remainder of the interview usually focuses on those projects instead of other coursework-based learning experiences. As another example, one of the authors participated in internship interviews with students from the program and compared their answers to those of their peers outside the program. He found that students who participate in the program's project-based curriculum are able to provide more details in their responses as well as more accurately assess their own interview performance. These results suggest that the program has been effective at designing transdisciplinary learning experiences that aid student internship placement.

Results from student project-milestone deliverables suggest that the prototypes created by student teams have become more advanced, indicating that the program is succeeding at its second aim of sociotechnical innovation. For example, by the end of the first-year studio course, students are expected to create a low-fidelity prototype. Low-fidelity prototypes, according to Usability.gov (2022), are "paper-based and do not allow user interactions. They range from a series of hand-drawn mock-ups to printouts" (para. 7). High-fidelity prototypes, in contrast, deliver a more realistic user experience (para. 8), often through computer visualizations or a robotics kit. Although in the first year of the program, most student teams produced low-fidelity prototypes, the norm is now for students to create multiple, high-fidelity prototypes despite being in their first year. In fall 2021, a first-year team completed research on autonomous systems in support of NASA's Artemis III mission. The deliverables included a technical prototype of a robotic drill and a visual of the end product in computer-aided design software (CAD). Across student projects, other project-development milestones like risk matrices and business plans also have become more advanced, perhaps due to additional mentorship from industry partners specializing in those areas. The production of more advanced project-development milestones indicates that the program may be encouraging sociotechnical innovation.

Industry-partner feedback, however, suggests that the program has room to achieve more sociotechnical innovation. Industry partners regularly question how a particular solution is innovative or technologically advanced. For example, before project-development milestone presentations, student teams prepare answers for common questions like "What is the enabling technology?" and "What is the innovation?" Feedback from industry-partner questionnaires also picks apart common student assumptions. Many business plans submitted in the first- and second-year studio courses assume that prototypes commonly receive thousands of dollars in venture capital or other income. As well, many first- and second-year project teams propose machine learning as an innovation without demonstrating how their prototype will collect, analyze, or make decisions based on data. Although faculty have responded with additional course material about project funding and use of machine learning in prototypes, these results may indicate room for growth on this particular programmatic outcome.

Discussion

Results from this study contribute to conversations about the value of employing co-creation methodologies to develop transdisciplinary programs with industry and nonprofit partners. Our co-creation model facilitating transdisciplinary education and sociotechnical innovation also may provide opportunities for technical communicators who want to adopt studio coursework as an alternative or in addition to the service course. Those interested in adopting the co-creation model or employing co-creation methodologies in their programs, however, should be prepared to mitigate several challenges.

We use this section to discuss these challenges, including how to enable connectivity between industry partners, faculty, and students; to manage different expectations for the program; and to value the varied expertise of program stakeholders. We also discuss plans for more robust programmatic assessment and explore the potential replicability of the co-creation model.

Connectivity

Managing connectivity between stakeholders is one of the most difficult tasks in this program—and likely any program. The success of our co-creation model depends on the continued connectivity of our 75 industry partners. We manage connectivity by implementing feedback pathways between faculty and industry partners and showing these stakeholders how we are changing the program based on their ideas. For example, we host three on-campus events[5] and three hybridized events per academic year. These events regularly draw upward of 40 individuals and demonstrate the program's commitment to collecting their perspectives on the industry-motivated outcome areas that

5 We did not host these events during 2020 and hybridized events in 2021.

students examine in studio coursework. Sometimes, however, industry partners provide feedback that cannot be deployed in the program. In fall 2021, all members of an industry-partner focus group enthusiastically agreed that project development milestones should become a "Shark Tank" style pitch competition. Faculty disagreed, citing concerns about the impact of a contest on the overall learning environment. In this case, the moderator was able to redirect the focus group's attention back toward outcome areas, which are the responsibility of the industry partners to set. In this case, and other cases, ensuring connectivity between stakeholders requires regular communication about each stakeholder's roles and responsibilities within the program.

Even after ensuring that industry partners able to see evidence of their ideas at work within the program, we note that industry partners are mainly "a coalition of the willing." Although on-campus orientation and Expo events are well-attended, some student teams report having to seek out multiple mentors before finding one who has the time to regularly advise their project. Mentoring student teams is not an easy task; as industry partners find, students expect to meet with their industry partner(s) every other week online and touch base at the in-person events during the academic year. Industry partners review student deliverables, give feedback on presentations, and serve as liaisons to their industrial sector. Our industry partners report an average time commitment of 8 hours per month, yet we have found ways to maintain connectivity despite the time commitment of mentoring. Industry partners are more likely to agree to mentor student teams if those teams ask them directly for mentorship. Based on this finding, faculty teach students how to contact industry partners and remain in communication with them, but students are responsible for making the connections. Demonstration of student interest and motivation tends to beget interest and motivation in return from industry partners.

Expectations

Including industry partners within the co-creation model also means navigating conflicting expectations about their presence in the program. Incoming students often believe that industry partners are there to give them jobs as part of a feeder program. This mistaken belief prompts a welcome discussion about stakeholder theory, in which students are reminded that industry partners are not avatars of their employer but are people with their own skillsets and expertise. In alignment with this challenge, when students propose projects, they must secure an agreement with an industry partner before the project pitch. These actions diminish mistaken beliefs about feeder programs; however, the "give them jobs" argument is harder to navigate. In truth, many industry partners are able to use their professional connections to help students progress through the internship hiring process. Neither faculty nor program administrators have asked industry partners to utilize their professional connections in this way. When industry partners have mentored students through the hiring process, they have done so because they served as a project mentor to the students over the course of multiple semesters and wanted them to succeed. Some students may have trouble interpreting this nuance of industry mentorship, though, and may believe that mentorship is a ticket to a job. (See Table 4.) Table 4 documents Student 4's quote that the experience of working with industry partners "did not really benefit me when it came to internship opportunities," evoking the false feeder program expectation. Faculty have responded to this concern by providing collaboration and networking resources to students with the aim of learning that interacting with multiple professional mentors is a lifelong process that improves professional development.

Because the co-creation model results in perspectives and feedback from all stakeholders, we can be challenged to navigate the different feedback we receive from these stakeholders. Students in particular report difficulty parsing the multiple perspectives present in feedback they receive from their course instructors, faculty mentors, and industry partners. Student evaluations of the program exemplify the frustration that students experience as they receive conflicting advice from the many mentors on their project team.

Table 4 shows student feedback about experiences with industry partners. Although frustrating for those teams trying to determine how to move their project forward amid multiple opinions, faculty have noted that navigating conflicting opinions is a common workplace experience and one that is likely to be useful for students' professional development.

Expertise

The program model also yields interesting questions about expertise, particularly regarding the disciplinary expertise(s) of students and faculty. As earlier results suggest, students learn transdisciplinary skills in our program through both formal and informal means. Insisting that students learn transdisciplinary skills can result in crossing disciplinary boundaries, sometimes uncomfortably. Students often report discrepancies between the projects assigned in disciplinary coursework

Table 4. Selected student reports of frustration with different advice given by project mentors as well as different communication and collaboration styles

Student	Comment about Conflicting Advice or Communication from Industry Partners
1	When we presented to industry partners, it seemed like they were unaware of where we were at in the course content. For the PDR presentation, they asked mainly business case questions when students had two days to put theirs together and were unfamiliar with the details they were looking for.
2	I think overall it was really interesting to meet and talk to them all, but I think a lot of them don't fully know what we're doing and then there's some awkward moments of "oh we're not actually doing this"
3	My experience with the industry partners was good. Although they might not have had as much knowledge about the specifics of our projects, they asked good questions and were engaged.
4	I found that interacting with these people did not really benefit me in ways that I had originally thought. I was stressed for the presentations I had to with these people present, but the after conversation did not really benefit me when it came to internship opportunities.
5	My experience with industry partners was limited so my opinions are also limited. I felt that some of the questions that the industry partners asked were very outside of what we learned so it sometimes became difficult to understand how to approach their feedback. A potential solution to this is to debrief those being presented to so they have a general sense of what the students know so their questions don't go to outside of it.
6	It was often hard to find times that worked for them and us. Maybe establishing a weekly office hour where the industry partners mark off a time to meet with students in the program. While this is likely not feasible since they are working professionals, some sort of system should be established to streamline this process.

Table 4. Selected student reports of frustration with different advice given by project mentors as well as different communication and collaboration styles (cont.)

7	I enjoyed the first meeting we had with them, but I felt very unprepared for it. The biggest issue I had is they're incredibly hard to get a hold of. I've emailed many and only one has ever responded, even though some directly gave me their cards. Many asked engaging questions and were wonderful to talk with during the expo and early presentation, but poor when online.
8	It was awesome that the industry partners were so available and willing to help. However, they were often very confused on how the project worked/what our problem space was, and how to help us beyond just giving us their thoughts.
9	I think some industry partners do not completely share CHDPs vision for maintaining and improving the human component of the system (as seen by the questions asked to the cobot drilling team)
10	I felt like it worked very well this semester, and we had less problems with Industry partners going off topic and making our project more confusing. All of the industry partners we met with this semester were very helpful.
11	There was much less interaction between the groups and the POPs when compared to freshman year. Also they seem to have way more technical difficulties than average people.

versus the industry-motivated projects assigned in the program. These discrepancies play into conceptions of student expertise. When students join the program, they often believe that their major determines the work they do on a team. Engineering majors commonly believe that they will build the prototype, design majors that they will make the presentation, business majors that they will write the business plan, and communication majors that they will write the project report. As students learn from faculty mentors and industry partners, however, this siloed approach to expertise has resulted in the disparate feedback and haphazard communication that they find so frustrating. Yet as students continue to complete coursework in their home discipline, students find themselves caught between two different educational models.

Traditional perceptions of disciplinarity cause further problems for students hoping to apply for internships outside their traditional major field. Students majoring within the College of Engineering (approximately 30% of students in the program) rarely seek internships outside engineering. Students outside engineering, however, often are interested in leveraging their status in the program to apply for internships outside their traditional major field. We have found that getting to the interview is the biggest hurdle that non-engineering students must surmount for internships they are otherwise qualified for. One of the authors reports issues with application portals rejecting applications from students not majoring in engineering, despite those students having both the coursework and project-based learning experiences to validate their expertise. In these cases, students must rely on connections with industry partners to get past the application and into the interview pool. This process is frustrating for everyone involved, and unsurprisingly, some students return to seek internships within their traditional disciplinary expertise. This problem illuminates a potential area of growth for the co-creation model; if our stakeholders are truly enthusiastic about transdisciplinary education and sociotechnical innovation, we hope that they will liaise with human resources to shift the application portal's programming. As we have found, however, sometimes industry partners do not know how the application portal at their company works. This issue remains a concerning limitation for students hoping to apply their transdisciplinary expertise outside of their traditional major field.

The question of (trans)disciplinary expertise also occurs with faculty teaching in the program. Core faculty are often regarded subject-matter experts within their discipline but may have trouble convincing students, industry partners, and other faculty that their perspectives are valuable outside their traditional disciplinary fields. Moreover, faculty have found themselves reckoning with difficult questions about the disciplinary place of the coursework they teach. For instance, one of the authors is designing the six credits of technical communication coursework that all students in the program take. Although some coursework in the technical communication sequence is typical for the field, like professional writing and user experience design, students also receive instruction that is less common in technical communication coursework, like digital prototyping. In this case, these instructional differences provide interesting conversations about conventions of technical communication pedagogy.

Moving Forward: More Robust Programmatic Assessment and Scalability

The program's pilot phase is expected to end in academic year 2023–2024. At that time, program administrators and faculty are expected to provide more robust programmatic assessment data about 1) student growth in the program, 2) necessary transdisciplinary coursework, and 3) scalability. We address our plans for achieving these goals below.

Student growth in the program. Most programmatic assessment is currently qualitative. Whereas internship and other numerical placement data are useful to support our claims about the program's value, we aim to increase our capacity for quantitative assessment through analysis of student deliverables. For example, vector analysis of student project reports and process books may provide quantitative evidence of change in discourse over time. Results may then be used to support claims about the impact of the program on student growth.

Necessary transdisciplinary coursework. Our stakeholders are interested in determining what and how many courses are necessary to deem an education transdisciplinary. Although we do not necessarily endorse this approach to transdisciplinarity, we intend to examine student project deliverables and overall impact on academic experience across other university studio courses. Because our program is the only program that requires transdisciplinary coursework in conjunction with studio enrollment, results could yield interesting conclusions about the value of transdisciplinary programs versus transdisciplinary courses.

Scalability. Our industry partners are interested in scaling this programmatic model for use at other universities. Ongoing programmatic assessment efforts are focused on determining the essentials for implementation, including funding amounts, core faculty makeup, likely academic programs to work with, and industry partner recruitment from additional governmental and nonprofit sectors.

Limitations

We note several limitations with potential replicability of this model for program design including place within the university, availability of funding, and recruitment of industry partners. First, this program is housed within an honors college. The already interdisciplinary nature of our institutional home assists with our ability to recruit faculty from across disciplines and enroll students from different majors. Deploying the co-creation model within a more defined disciplinary home might lead to constraints in these areas. Second, the funding situation in our program may allow us more flexibility to make programmatic decisions that support our stakeholders. Finally, we note that our ability to recruit industry partners may be influenced by our institution's reputation as a large polytechnic university.

Conclusion

This project used a co-creation method to develop a transdisciplinary program focused on sociotechnical innovation. Using this model for co-creation, we worked with stakeholders to determine and implement goals for programmatic outcome areas, coursework, and project-based learning. Co-creating these elements of a program with stakeholders, including industry partners and students, has resulted in programmatic growth and strengthened the program's focus on transdisciplinary education and sociotechnical innovation. We examined the co-creation model's impact by analyzing programmatic assessment data from industry partners and students, as well as results from student project development milestones.

Results suggest that the model has influenced program growth due to the addition of more industry partners, more participating majors, and increased numbers of students who have expressed interest in joining the program. The program's focus on transdisciplinary education and sociotechnical innovation is supported by student experiences at learning skills outside their home discipline, internship placement information, and an increased number of high-fidelity prototypes delivered by student project teams.

Technical communicators who seek to engage stakeholders within program design via co-creation methodologies should be prepared to codify pathways for stakeholder connectivity to their program's students and faculty. These pathways for stakeholder connectivity facilitate conversations about expectations and expertise of different stakeholders within the co-creation model.

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