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Assistive Technology and Human-Centered Engineering Design: Partnership between a School that Serves Students with Extensive Support Needs and a Human-Centered Engineering Program*

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In this paper, an Assistive Technology Professional (ATP) and two engineering instructors share how an engineering program and a school that serves students with extensive support needs develop a partnership based on engineering design and the development of assistive technologies. We use a qualitative cross-case analysis approach to understand and share the development of the partnership over three sequential courses, each of which we frame as a case. While there are differences in the cases informed by the time in the partnership they took place, prioritizing front-end design vs. prototyping activities, and different learning outcomes for the courses, some strong themes to understand key aspects that inform the partnership emerge. These themes include building sustainable partnerships of trust, the role of people as connection agents, centering issues of power and justice, and engineering design as a medium to support partnerships.

Keywords: assistive technology; authentic partnerships; design justice; human-centered engineering

1. Introduction and Background

In this paper, we use a cross-case analysis approach to share experiences from a partnership between a school that serves students with extensive support needs and a newly created human-centered engineering undergraduate program. The authoring team comprises an Assistive Technology Professional (ATP) and two engineering faculty who have taught first-year engineering design courses in partnership with the ATP's school. In the paper, we will highlight how intentional iterative engagements between the two sites (similar to an organic design-based research approach) fosters a mutually beneficial relationship that continues to be formed between the two entities. While engineering students practice human-centered design and prototyping skills, the partner school teachers, therapists, and medical professionals receive technologies tailored for their students.

Providing authentic contexts for engineering design learning is an effective pedagogical approach since it helps students develop skills and use them in real-world contexts, which is rewarding and aids identity development [1–4]. Further, students may find such contexts *personally* or *situationally* interesting, significantly impacting their learning and development [5, 6]. Students find learning *personally interesting* when they find the experience/context interesting (e.g., plants, fashion, etc.) and *situationally interesting* to students finding the experience/context in which they learn interesting (e.g., interactive, project-based, etc.). Further, service-learning opportunities help provide pro-social contexts for students to practice and develop their engineering identities in [7–9]. Engineering courses, especially first-year and capstone project-based courses, have increasingly adopted authentic contexts for project-based engineering design teaching [10–12]. However, a reasonably understudied area is how these authentic contexts are made available to the students, including the partnerships that support and enable them. There has been some work in understanding the underlying values of partnerships in service learning settings, which includes values of reciprocity and respect [13–16], however how such partnerships are formed and developed in engineering design contexts, how engineering design serves as a facilitator for such partnerships, and the resultant outcomes for the partner organizations, remains understudied. In this paper, we share our experiences across three sequential cases (of courses) of forming such a partnership between an engineering department and a school that supports students with extensive support needs.

2. Context

The institutional context for this work is a liberal arts research university in the U.S. Northeast with an engineering program that admitted its first cohort of students in 2021. The program is being

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developed around the theme of human-centeredness and extensively uses design- and liberal arts-based pedagogies to promote societal responsibility and formative education. In this paper, we share experiences from a partnership that has formed between the program and a school that serves students with extensive support needs (referred to as partner school or PS hereon). Two first-year courses, one taught by a founding faculty member and another by a visiting faculty member to the program, have worked with the partner school to design and develop innovative technologies for students at the partner school (PS) for various design contexts. This partnership has enabled engineering students to apply their engineering design knowledge in authentic contexts and develop solutions that support the PS students. At the same time, the PS has been able to re-think and develop ways to serve their students with the help of technology. Our partnership is unique in that we work with two different student populations, yet both meet learning objectives through collaboration. However, as we share the benefits of the partnership, we find it imperative also to share the challenges and the inherent complexities of a partnership that could cause harm to several individuals involved (especially the students at the PS) and have an imbalanced power differential, especially in the realm of communication which is an essential aspect of engineering design.

3. Approach

The three cases we share in this paper are two instances of one course (C1V1, offered in Spring 2022, and C1V2, offered in Spring 2023) and one additional first-year engineering design course (C2). The courses were taught primarily to engineering students, and at least one of the projects in each course is a partnership with the PS that serves students with extensive support needs. Below, we share the types of data we collected and methods used to answer the research question: To understand how the relationship between an engineering program and a school that serves students with extensive support needs develops in the context of engineering design education.

3.1 Data

For C1V1 and C1V2, our data sources included students' coursework, which primarily comprised three design milestones they submitted over the half-semester project. The milestone captured their design journeys including problem scoping, crafting objectives and constraints, concepts generated, several prototyping phases, and self-assessment of projects meeting the design objectives and constraints. These milestones also included students' reflections on humanistic design prompts [17] to support students' critical reflections while practicing design. For C2, since the project in partnership with the PS comprised one of several projects that the students undertook in the course, our data was limited to the instructor and ATP's reflections on the course (both of whom are authors of this paper. The PS collects data regarding the number of active, intentional interactions with the assistive technologies created as part of this partnership, as part of their own outcome-based data collection. These intentional interactions contribute to the educational goals and objectives of the PS students. We also use reflections and experiences of the ATP and instructors in this qualitative case analysis approach.

3.2 Method

The plurality of experiences and richness of cases make a qualitative case study approach ideal for us to understand the nature and development of the partnership. Such an approach helps explore multifaceted phenomena via various lenses in real-life contexts [18, 19]. Below, we share details on the contexts of each case, a cross-case comparison table, and then a discussion on key themes that emerged in analyzing our cases. The cross-case analysis table comprises the guiding values and aims of each of the cases, the active members of each partnership, the outcomes for the engineering students as designed for and assessed by the instructors, the topics/foci of projects from each case, associated outcomes for the PS students based on the ATP's reflections, and ethical concerns that arose for each of the cases. Since a case study affords interrogation of multiple aspects of complex real-world issues, we further detail relevant themes from our data as mentioned to answer our above research question. The cross-case analysis table in the Context section and themes shared in the Discussion section were discussed and agreed upon over several meetings between all three authors using the data listed above (coursework for C1V1 and C1V2, instructor and ATP reflections, and the ATP's outcomes data). Following these meetings, the lead author created a draft of the table and a description of themes, which the other authors provided feedback on. The work shared here represents the final version of the cross-case analysis table and theme descriptions that all three authors agreed upon.

4. Context

4.1 Case 1 (C1V1 Spring 2022)

Introduction to Human-Centered Engineering is an

introductory engineering course in the engineering program that all students are enrolled in. The course comprises foundational engineering knowledge, like many first-year engineering courses [20], and a design project spanning half the semester (approximately eight weeks). In the first half of the semester, students complete exercises to learn engineering drawing, CAD, descriptive statistics, working with Arduinos, and prototyping techniques (including 3d printing, laser cutting, soldering, and sewing). For the project, the students are assigned one of the project contexts in teams of 3-4 based on their preferences. Case 1 comprises the first instance of this course offering i.e. in Spring 2022. The project contexts are listed in Table 1.

4.2 Case 2 (C2 Fall 2022)

Innovation Through Design Thinking is an introductory course focused on helping students learn and practice the design process. The instance of the

Table 1. A table showing the cross-case analysis of key aspects

	Aim & Active members	**Outcomes for engineering course**	**Project contexts**	**Outcomes for partner school**	**Ethical concerns**
Case 1: C1V1 Sp 22	Initiation of partnership, Determining mutually beneficial outcomes. Author 1, Author 2, School head, Teachers, Therapists, Nurses, Students (PS and engineering).	• Solving engineering design problems in a human-centered context. • Developing emotional intelligence, an understanding of wicked problems, and compassion early on in their engineering program by experiencing the complexities of supporting the PS students. • Increasing awareness of the abilities of the PS students and the lack of engineering/tech resources to help them.	Life skills including laundry, yard work, running a coffee shop, and telling the weather in their morning meetings.	• Since the PS students have constantly changing challenges, this partnership helped quickly address their needs using engineering design and technology as they arise. • The PS students are empowered with access since the level of customization of technology possible through this course is unparalleled when working with industrial vendors (from ATP reflection).	• We were unsure about the outcomes and if it was worth everyone's time. • We were concerned about the power imbalance (especially because COVID protocols restricted interactions between engineering and PS students).
Case 2: C2 Fa 22	Work on preliminary design while working with an authentic partner. Author 2, 3, Occupational Therapist, Students (PS and engineering).	• Engaging with an authentic partner while working on a design project. • Engaging in front-end design activities. • Using speculative design to create initial design solutions that could be built on through future work.	Adapted drinking cup to meet the needs of individual PS students.	An unexpected outcome of the partnership, in this case, was that PS staff became more invested in the partnership and began to understand the possibilities and benefits (from instructor and ATP reflections).	We recognize that creating the solutions required time investment from the PS but needed more fabrication work to finalize them for use.
Case 3: C1V2 Sp 23	Developing protocols for sustainability. Author 1, Author 2, School head, Teachers, Therapists, Nurses, Students (PS and engineering). We have observed more participation from the PS students' families as they see value in this partnership, e.g., one of the families requested an assistive dog bowl for home.	(In addition to Case 1): Provide a creative context to develop skills in working with simple electromechanical systems within a human-centered engineering design context.	STEM Education, Coffee shop, Morning meeting, Engineering the environment, Laundry, Food prep, Accessible OT/PT activities.	(In addition to Case 1): Benefit Progress and Increased Engagement: When PS students are empowered, they become motivated to achieve more. When they actively participate in an activity such as a coffee shop, they get positive feedback and attention, which positivity motivates them to interact in other areas (from ATP reflection).	• We were concerned about overburdening particular stakeholders in the partnership. • The power differential between users and designers. Though in the second iteration of the course, students from both schools interacted (due to limited COVID protocols). E.g., The engineering students could see how PS students use alternate communication methods to express opinions and preferences.

Fig. 1. Variably weighted and switch-activated pinewood derby cars and track. Project context: STEAM education.

Fig. 2. Automatically scoring and height-adjustable hoop. Project context: March madness-themed OT/PT activity.

Fig. 3. Moveable mounts installed around the school that announce the location. Project context: Engineering the environment for accessibility.

Fig. 4. Sip and puff and light touch switch operable communication board. Project context: Engineering for communication.

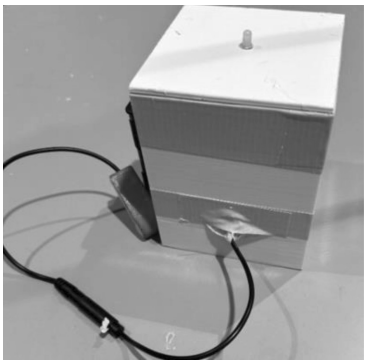

Fig. 5. Laundry color detector. Project context: Laundry life skill.

Fig. 6. Switch-operated milk dispenser. Project context: coffee shop.

course that we report on here was taught in the Fall of 2022. The course is structured around three design challenges, where students apply the design process working on interdisciplinary teams. First-year human-centered engineering students can take this course as a required course. However, it is open to students from all majors and years from across the university. The design challenges are scaffolded in that they are intended to help the students practice different aspects of the design challenges. In the first design challenge, students focus on the first part of the design process discovery and design empathy. In the second, students focus on the later part of the design, including iteration and prototyping. Students work on a general design challenge during these first two challenges without a specific stakeholder or client. In the final and third challenge, students focus on the complete design process for a real stakeholder.

The final design challenge for this class was focused on an assistive technology design challenge for the Campus School:

> "How might we create an adapted drinking cup that Campus School students can functionally use during mealtimes, that can be adjusted to meet individual unique needs, and that provides ease of use for caregivers using a human-centered design approach?"

4.3 Case 3 (C1V2 Spring 2023)

This is the second iteration of the course in Case 1 which was offered in Spring 2023. The broader learning outcomes and goals of the course remain the same. However, this course aimed to workshop a sustainable and clear partnership model between the engineering program and the PS. The reasons for this include the doubling of student numbers in the course (which is expected to be the steady state of the department), and we collectively discussed the importance of documenting and standardizing some of the processes to contribute structure to future iterations of the partnership with potentially additional new stakeholders.

Also, an additional mini-project was added to the course to scaffold skill and concept development for the final project. In iteration 1, the teaching team noticed that while some students had a background in working with physical mechanisms and simple circuits to create working prototypes, others did not. Hence, before starting the half-semester-long project in this second course iteration, the students worked on a short prototyping challenge to develop skills to create simple electromechanical systems and make electrical systems switch accessible. Based on discussions between the project partner and course teaching team, a few project contexts from last year were used, and some new contexts were introduced – they are captured in Table 1. In Figs. 1–6, we share images of some of the students' final projects (we have IRB approval to share anonymized student work from the three design milestones submitted as assignments in the C1V1 and C1V2 courses).

5. Discussion

5.1 Similarities, Differences, and Evolution

There are several similarities in the three cases we share above. Namely, the guiding values of building sustainable partnerships intentionally based on trust, the role of people as connection agents, cognizance of issues of ethics and power, and engineering design as a medium to support partnerships. We will discuss these similarities in the remaining subsections of the discussion section.

In terms of differences, they are primarily informed by when in the partnership's timeline the course took place, the intended outcomes for the course and the PS students, and to an extent, the space afforded to front-end design activities vs. prototyping activities in the course. Case 1 was the first instance of the partnership within a formal course, so initiating the partnership and workshopping possible outcomes was an important goal. For Case 2, while a preliminary partnership existed, it was still new to the course instructor and the students in their first semester of college. Also, unlike Cases 1 and 3, where a significant focus was on prototyping, Case 2 focused on front-end design activities and developing humanistic design skills, including empathy. For Case 3, we were able to move towards measures of sustainability since we had prior experiences to draw from, including supporting students to develop fundamental skills in working with simple electromechanical systems.

5.2 Building Sustainable Partnerships of Trust

An overarching theme across the cases shared here and in conversations with the stakeholders involved in this work is the importance of trust. Multiple and iterative engagements in the formal curriculum, informal activities like student clubs, and maintenance of the technologies created as part of the courses all provide opportunities for the individuals involved to connect over tangible artifacts, share experiences, and develop relationships of trust. Building such relationships of trust was extremely important in the context of our project partnership since the PS serves students with extensive support needs, the engineering students involved are in their first year with limited prior engineering knowledge, and there is often a need to repair and maintain several of the developed technologies.

5.3 The Role of People as Connection Agents

In addition to developing relationships based on trust, on analyzing the cases we shared above, we uncovered that people or connection agents that hold the partnership together, give it direction, and develop it further are essential to our partnership. Connecting this to the theme of developing trust, trust is developed between individuals and not necessarily organizations or departments. These connection agents include but are not limited to: the Active Technology Professional (author on the paper), leadership at the partner school and engineering department, staff (including teaching, nursing, PT/OT) at the PS, administrative and Makerspace/shop staff, the students in each of the cases, the course assistants and the instructors. Each of these individuals upholding the value of trust and recognizing the importance and novelty of

the partnership greatly contributed to the work we share here.

5.4 Centering Issues of Power and Justice

There are several issues of power and justice that we have unpacked in our discussions while collaborating (as the authoring team of this paper) with our colleagues and students. The first is the question of *who is helping whom?* While at first glance it might appear as though the engineering students are helping the students at the PS, the students from Case 1, when prompted to think about power in the partnership, often brought up how they were the ones being helped by having an authentic context to learn and practice engineering. Secondly, the engineering students were prompted to (via reflection prompts in their design milestones) think about what preconceptions of disability they brought to their design work, including normative beliefs about physical ability and conceptions of activities one should engage in at school. Thirdly, while all cases had cycles of iteration via feedback from the PS, it is important to acknowledge that the design approach did not follow ideal participatory design principles and was essentially designed for the needs of the PS staff as opposed to the students who would be using the technologies. Also, the ATP notes that the PS students are often more motivated to use the items created during this partnership. A possible explanation is that the engineered items are made on time to specifically address their current needs. This likely motivates the PS students since their medical conditions and needs often change, and hence the speed at which the custom solutions are delivered greatly empowers them.

5.5 Engineering Design as a Medium to Support Partnerships

An important theme that emerges from the reflections of the authoring team and collaboration members is how engineering design presents a rich context for the partnership to develop. Partnerships can have several goals, and ours being based on using engineering design to create assistive technologies contributes to the nature of the partnership. By framing the students' experiences at the campus school as engineering design problems, the staff at the partner school, the engineering students, and the instructional team were able to use engineering design techniques and principles to develop potential solutions. These include front-end design activities (the divergent phase of problem identification and understanding the context), engineering drawing and CAD, reflective practice, engineering ethics, iteration, and documentation. Engineering design provided a shared language for the partnership and helped situate the learning and outcomes for students on both sides. With Case 3, we believe we initiated but have not completed a sustainable engineering design approach that provides a framework for sharing, meeting, and discussing expectations.

6. Limitations and Concerns

As captured in the above theme on centering issues of power and justice, while we attempted to make intentional choices in the design of the learning interventions reported here and in the writing of this paper, we would be amiss if we did not acknowledge potential areas of limitations of our work. Firstly, it is important to recognize that the engineering students likely gained more from this partnership than the PS students and staff, and they and their instructors held more power over the final designs. Further, visiting protocols and non-traditional ways to moderate communication between the engineering and PS students, which was even more difficult with COVID-related restrictions, impacted how participatory the design activities reported here could be. We are also aware of the broader and valid critique of the traditional conceptualization of assistive technologies and design for disability and how a more expansive conceptualization may challenge the dualism between designing in general and designing for disability [21]. While we introduced students to these ideas, there is still plenty of room to re-design these courses with more participatory and design for empowerment techniques in mind.

7. Conclusion

In this paper, we share experiences from a 2-year-old partnership that, as of the writing of this paper, is continuing to develop. Outside of the cases we share, many students who have completed the course have stayed connected to the PS. They continue to use outcomes from the courses and the university makerspace to create "just in time" assistive technology to solve problems of the PS. For example, making a sideliner for a PS student, volunteering at the PS for four-hours weekly, helping fix switches and mounts that break, and even participating in fundraising 5k and relay run events to raise money for the PS. Several other students have used CAD to create custom artifacts for the PS, including visual prompts, jelly bean mounts, etc. These examples connect back to the role of people we highlight as connection agents and the importance of developing sustainable partnerships of trust that we also shared in the discussion above. We plan to continue to further

nurture this partnership with other courses (e.g., the statics instructor is interested in using projects shared here to teach concepts), and we are considering running an alternative version of the project for upcoming iterations of C1 where instead of developing new technologies the students help fix and further iterate on technologies created by cohorts before them.

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