education sciences

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Embracing Co-Design: A Case Study Examining How Community Partners Became Co-Creators

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Abstract: Co-design increases the number of voices in a design project, which enhances the experience for all co-creators and produces a better product. A case study is presented of a ten-month co-design project-based learning experience between two engineering design students and two community partners during a first-year engineering design course, which resulted in the implementation of the device across campus. This paper evaluates the elements of co-design in the design process that was employed, documents the design product that was produced, and examines the experience of the community partners through a qualitative study. Through a retrospective examination of artifacts and files, the design process demonstrated an increase in the amount of collaboration between co-creators as the project progressed and identified 15 iterations of the design. Comparing the experience of community partners throughout the design process, five themes emerged from the semi-structured interviews: (1) emotional effects, (2) physical and mental effects, (3) productivity, (4) safety, and (5) job satisfaction. Documenting the experience of community partners throughout the design project can encourage educators to adopt co-design practices in project-based learning.

Keywords: co-design; co-creators; project-based learning; end-users; community partners; first-year design; design

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Citation: Murdock, L.; Osgood, L.; McCarvill, L. Embracing Co-Design: A Case Study Examining How Community Partners Became Co-Creators. *Educ. Sci.* **2023**, *13*, 492. https://doi.org/10.3390/educsci13050492

Academic Editors: María-José Terrón-López and Paloma J. Velasco-Quintana

Received: 19 February 2023
Revised: 20 April 2023
Accepted: 4 May 2023
Published: 13 May 2023

1. Introduction

Project-based learning is found in numerous pedagogies within engineering education, particularly in design courses wherein students follow the design process to solve a specific problem. Often, design projects pair students with community partners who have authentic problems to solve. In co-design, one form of human-centered design, the circle of designers is widened to invite people affected by the design into the development process. The co-design mindset shifts from designing for a user to designing with the people who are affected by the design [1], thus increasing the number of voices in the design process. This inclusive practice ensures the desires, opinions, and concerns of people who are affected by the design are incorporated [2], which improves both the final design and the experience for all participants [3]. Incorporating community partners early in the design process has been shown to produce more novel ideas and ergonomic products [4]. Additionally, communities tend to embrace the solution more and support its long-term maintenance if they are involved in the decision-making [5]. Reynante [6] advocates for participatory design as a matter of social justice to help shift student mindsets from accepting passive community involvement to more inclusive participatory design, shifting from a design-for-charity mindset, which connotes inherent power structures, to a more inclusive design-for-justice approach, empowering all stakeholders within a project and producing more equitable outcomes. However, Harrington et al. [7] warn that there is the potential to marginalize community partners (despite good intentions), particularly when working with systematically underserved populations. Additionally, though there are many benefits to engaging community partners in the design process, the barriers include additional planning for interactions, which is more time consuming for instructors and community partners [8,9], and a potential geographic divide between community partners and students [10].

Additionally, while much of engineering pedagogy documents the student and instructor perspectives, such as in [4,11], research is needed to document the experience for the missing co-designers: the end-users or community partners. For example, in [12], community partners are described as essential during project definition to ensure their expectations align with the project definition, but their participation or perspectives are not mentioned again throughout the rest of the paper. The study documented the perception of the students but not the perception of the community partners. While an understanding of students' and instructors' perspectives is an important element of engineering pedagogy (and one article is not representative of all pedagogical literature), the perspective of the person who will be using the design is vital to fully capture the design experience.

A lack of input from community partners was also documented in a literature review of 38 engineering community-based design projects, in which only five of the papers (13%) included evaluations from community members [5]. Similarly, a systematic literature review of projects with community engagement found that only 14 out of 120 articles (12%) mentioned the perspective of the community partners [13]. Thus, more consultation on the impact of the projects on communities is needed [5].

Welcoming the community partners to participate in the assessment and evaluation of a project offers a more inclusive and effective implementation of co-design. In a literature review of 49 papers, Mazzurco and Jesiek [14] developed five elements that lead to a successful community design project, two of which are: collaborating with local champions and harnessing local resources and expertise. These recommendations should extend to documenting the design process as well. For example, researchers documented the experience of co-designers in health service [15], and similar accounts are needed in engineering education. What do community partners experience during a project-based learning course? Do they feel like end-users or co-designers? By excluding the community partners from research, we are effectively silencing them, which does not build trusting relationships or integrate social justice (two of Mazzurco and Jesiek's [14] recommendations).

Recorded accounts from community partners can aid to inform and adapt practice and future implementations. Additionally, documented experiences are vital data points, which can be synthesized to develop models and praxes for further research. To document the community partners' perspective during a design project, two engineering students and their first-year design-course instructor performed a qualitative study on one of the projects from that design course. The design consisted of a clip mounted on a mop bucket to secure the mop to the bucket to facilitate navigation and safer transportation. The project was selected as a case study because the engagement of the two community partners (who work as custodians in the engineering building) and the empathy of the two first-year engineering students extended the two-week design assignment into a 10-month iterative co-design experience, resulting in the implementation of the product to multiple users across campus. This project began by employing the design process for end-users, but it concluded as a co-design process between co-creators. This case study presents an opportunity for the engineering students and course instructor to apply a retrospective lens [2] to examine how the project developed into a co-design experience and to perform a qualitative research project documenting the experiences and perspectives of community partners through semi-structured interviews (approved by the institutional research ethics board).

The two research questions are: (1) Which stakeholders were involved in each step of the design process? (2) What was the experience for the community partners throughout the design project? Becoming aware of how each stakeholder was engaged throughout the previous design process (question 1) is the first step towards adopting co-design in future projects. Then, we explore the experience of the community partners (question 2) to understand the impact the project had on them. The first research question is necessary to establish and understand how each stakeholder was involved, particularly because this is a reflective exercise. This will also inform and shape the interpretation of data from the second question. The first question can encourage educators to engage in reflective activities to evaluate whether they are encouraging co-design in their courses, and it can model one evaluative approach.

This paper provides background on co-design and empathy, examines the design process, presents the resulting product, and discusses insights gained from community partners' experiences. It is hoped that the community partners' perspective will encourage engineering educators to promote co-design in their project-based learning pedagogical practices and researchers to welcome the input of stakeholders throughout the design process, building towards more inclusive design, research, and educational practices.

2. Background

To provide context for this paper, the background section contains descriptions of two foundational concepts for this research: co-design and empathetic design. Upon reflecting on the experience, the students recognized that empathy for the community partner motivated their involvement to continue beyond the two-week conceptual design to a co-design project that resulted in numerous prototypes designed by four co-creators. Therefore, it is necessary to document the role of empathy in the design process and understand co-design as a design pedagogy. A note on terminology: though sometimes used synonymously, co-design and co-creation have varying meanings throughout the literature. In one instance, co-creation is a single act, whereas co-design occurs throughout the design process [16]. Thus, co-creation occurs throughout a co-design. However, in another instance, co-creation is described as the process by which co-design and co-production occur, inverting which is the overarching term: co-design or co-creation [17]. This paper uses the terms interchangeably.

Co-design is an umbrella term for collaborative design methodologies [17], such as participatory design, community design, and social design. Co-design is defined as "a methodology for actively engaging a broad range of people directly involved in an issue, place or process in its design and sometimes also in its implementation" [18] (p. 6). Co-design is essentially working alongside each other instead of in a vertical top-down or bottom-up model [18]. Often used to address complex problems, it is because of their differences (experience, skills, knowledge, and needs) that people collaborate through co-design [19], bringing their individual expertise and experience together to improve the design. A review of case studies conclude that co-design projects have improved project outcomes, long term effects, and creativity throughout the process [3]. Wallisch and Paetzold [20] credit the creation of safer, efficient, and more enjoyable products to designers who possess a better understanding of the characteristics of end-users. Collaborating with the end-user throughout the design process provides more opportunities to develop understanding.

Next, empathy was found to be a determining factor in engineers' abilities to succeed in complex global and intercultural environments [21]. According to Walther et al., empathy in design presents an alternative to designer-centered design, as designers focus on understanding the experiences and emotions of end-users [22]. Empathy helps designers to better understand the problem instead of jumping to a solution or fixating on the design itself. In empathetic design, everyday experiences and emotions can be turned into inspiration [23], which enhances the creativity of the design. Using a case study, Tuomala et al. [24] propose a process that incorporates empathy into design, including steps to identify empathy gaps and consider the consequence of the gaps. Through co-design, designers further develop empathy through regular interaction with end-users, which increases their design skills.

In co-design, the ultimate goal of product desirability goes beyond pure practicality and usability to encompass the entire user experience [25]. To better understand and improve their experience, the user must be involved in the design of the product itself. The roles of designers, researchers, and end-users are no longer distinct and separate. End-users may become designers during the co-design process, depending on their level of effort, interest, creativity, and expertise [16]. Scott and Mazzurco [26] compared five participation frameworks from the humanitarian engineering literature and identified decision-making, collective action, initiating action, and partnership as descriptors of more inclusive projects. Despite the implied participatory nature of co-design, in practice, not all participants are automatically converted into designers, as there are varying levels of involvement in each project. Thus, a reflective examination of a design experience can consider whether the desired level of collaboration was achieved.

3. Methods

To document which stakeholders were involved in each step of the design process (question 1), the engineering design students and course instructor employed a retrospective lens [2] of design artifacts with consultation from the community partners. The design experience was reconstructed as a case study and then deconstructed into design steps. First, design artifacts and documents including logbook entries, emails, CAD model dates, design reports, and interview transcripts were examined to chronologically define the steps taken throughout the design process, as well as to document the evolution of the design. Next, the role of each stakeholder was identified for each step, and the data were summarized in two ways: (1) as a case study narrative and (2) as a figure to document the design process and stakeholder involvement at each step. The level of decision-making, collective action, and partnership (as indicated by Scott and Muzzurco [26]) of stakeholders throughout the process is highlighted throughout the case study. To document the perspectives of the two community partners (question 2), semi-structured individual interviews were conducted by one of the engineering design students and the course instructor using a protocol approved by the institutional research ethics board. The two participants have four and twenty years of experience, respectively, and vary in physical stature and gender. They were asked about their experience before the design was implemented, after its implementation, and during the design project itself, using a pre-defined interview guide with prompts, which is available in the Appendix A. The questions were open-ended to allow the community partners to share their experience and allow for exploratory data analysis. They were not asked directly about how participative the process was, as this is one of the themes that was cultivated from the interview rather than prompted.

The interviews were recorded, transcribed, and lasted 45–60 min in duration. Field notes were recorded, and member checking was employed to give the participants the opportunity to review the transcripts. Thematic data analysis was performed as per the process outlined by Braun and Clarke [27], entailing independent coding by two of the authors, an inter-coder comparison, a discussion of the emergent themes, and a verifying review of the transcripts to ensure the themes match the community partners' experiences. Thematic analysis was employed due to the exploratory nature of the study to document the community partners' experiences. There were 23 codes produced during data analysis, which were grouped into five themes that contrasted the community partners' experiences before and after the design was implemented. The five themes were further categorized into eight sub-themes to elucidate the distinctions between pre- and post-design experiences.

Lastly, a table was produced to document whether the positive impacts of the design process on the community partners could have been achieved through traditional design practices or were only the result of a co-design experience. Though the level of co-design was not an initial research question, elements of co-design are present in the interview data and flow from the first question to document the roles of the stakeholders. Thus, the level of participatory co-design is included in the discussion.

4. Case Study Results: The Mop Prop

During the Fall 2020 semester, students in a first-year design course were assigned a two-week project-based learning opportunity to 'redesign an existing product' in teams of two. The pedagogical goals were to expose students to a short design process, practice user-centered design, develop CAD modelling skills, and communicate their designs through a presentation. The two engineering students for this case study initially chose to redesign a household product. Then, after a discussion with one of the community partners, a custodian working in the engineering building, the students changed their project to address the custodian's concerns. While the students were in the 'understand the problem' phase of the design process, the second community partner was recruited to participate in the project.

The basis for the design project is that the community partners use a mop and bucket system wherein the circular mop handle both loosely rests in a square groove in the bucket and is used to steer the bucket. The community partner identified that a device is required to restrain the mop handle more securely to the bucket to ensure the mop does not fall out of the groove while it is in motion. When transporting the bucket, travelling over tiles, hitting a small bump, or entering the elevator, the mop handle would often become displaced from the groove and fall to the ground. When this occurred, water would spill, and the handle could strike people as it fell, potentially causing multiple hazards due to a manufacturing flaw in the bucket.

At the end of the two-week period, the students produced a CAD model and presented their solution to the class. Because the students were emotionally invested in helping the community partners, the two community partners and two design students continued the project throughout 2021, working together as co-creators. Note that though the course instructor was involved in the design project, she is not considered a co-creator, because her role was primarily to create the scaffolding for the project and mentor the students through the design process.

After numerous iterations, the finalized device, "the Mop Prop", was 3D-printed using PLA polymer, which was selected because it is inexpensive, allows for rapid prototyping, and can withstand the harsh cleaning agents contained in the bucket. The device is attached to the bucket through two pre-drilled holes on the bar on the wringer assembly and is fastened using steel bolts, nuts, and washers. An early iteration of the device that utilized a 90° angle to hold the mop is shown in Figure 1, which displays how the device was affixed to the wringer assembly on the bucket during experimentation.

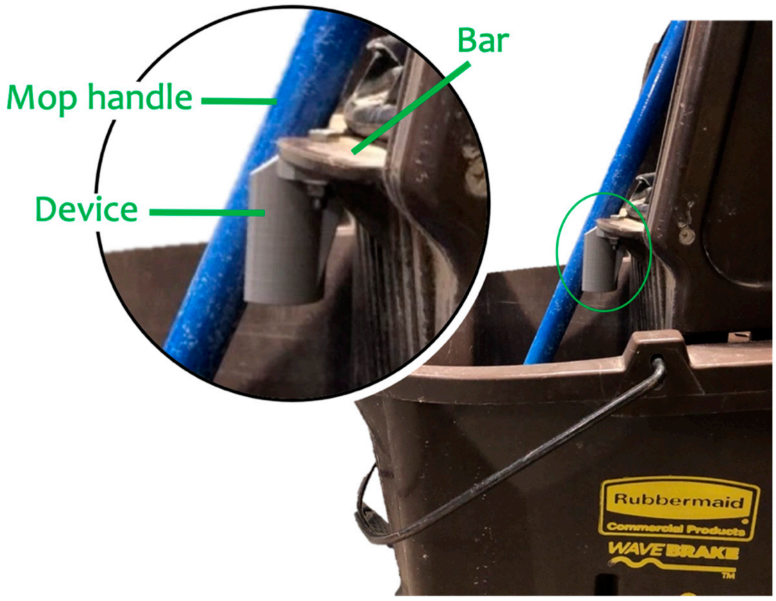

Figure 1. Image of early iteration of the device on the mop bucket.

The final design is shown in Figure 2 and incorporates an angled stem (34° from the horizontal plane and 4.6 cm long) to secure the handle. Because the handle is used for steering, an angled device allows for greater surface area between the handle and the fixture, allowing the mop head to naturally rest in the front of the bucket and providing a more comfortable position of the handle for the end-user. Overall, the device is 6.7 cm wide (maximized to fit the bar) and contains fillets to match the shape of the bar. The infill, inner diameter (2.9 cm), and opening (2.5 cm) were optimized to determine the ideal flexibility and strength to insert, secure, and remove the mop.

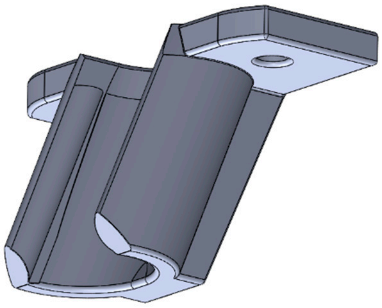

Figure 2. CAD model showing the final design of the device.

The influence of the community partners is apparent in numerous elements of the design and through decisions made in each design meeting throughout the project timeline. For example, early in the design process, the suggested edits were primarily focused on the ease with which the mop's shaft could enter and exit the device. This included widening the opening while adding ridges that secure the mop in place once inserted. The community partners expressed the need for simple retrieval of the mop with minimal force, so the device flexes to release the shaft.

Another design iteration initiated by the community partners pertained to how the mop naturally sits in the bucket. Initially, the device was designed with a purely vertical mount, as seen in Figure 1. However, this configuration was found to be impractical, as testing revealed that it was awkward and caused strain for the user when inserting the shaft. The re-design involved angling the mop's shaft, resulting in a more natural resting position within the bucket. Furthermore, adding angled, extruded cuts from the top of the opening enabled a tapered entry. This modification yielded several benefits, including reduced user strain during shaft insertion, improved stability, and enhanced maneuverability while holding the mop during movement around the building.

As the community partners gained more experience using the prototypes, they were able to stress-test the prototypes for long periods of time. Consequently, the four co-creators developed newer and more resilient models. To improve durability, a structural gusset was integrated into the back of the device, which improved the distribution of shear stress along the device's shaft. Additionally, the infill density of the 3D-printed design was increased from 20% (which was initially selected to reduce the cost of each iterated prototype) to 40% for increased structural integrity. Finally, as the community partners observed that the prototypes consistently sheared at a specific location, the orientation of the 3D-print was altered to distribute stress more evenly along the device. This modification allowed for stress to be applied across the layer lines as opposed to along them, resulting in more uniform stress distribution.

The duration of the project was ten months, during which time an iterative trial-and-error process occurred, as shown in Figure 3. The steps derive from the iterative co-design process documented in [28] and were adapted as follows: (1) for a local setting instead of global, (2) by moving the 'evaluate' step to allow for iterative prototyping, and (3) by splitting up the final step into 'implementation' and 'scale up' steps to reflect how the design was adopted across campus. Note: the scholarly contribution of Figure 3 is both to address question 1 and to encourage researchers to engage in a similar reflective activity to visually document how collaborative a design process is.

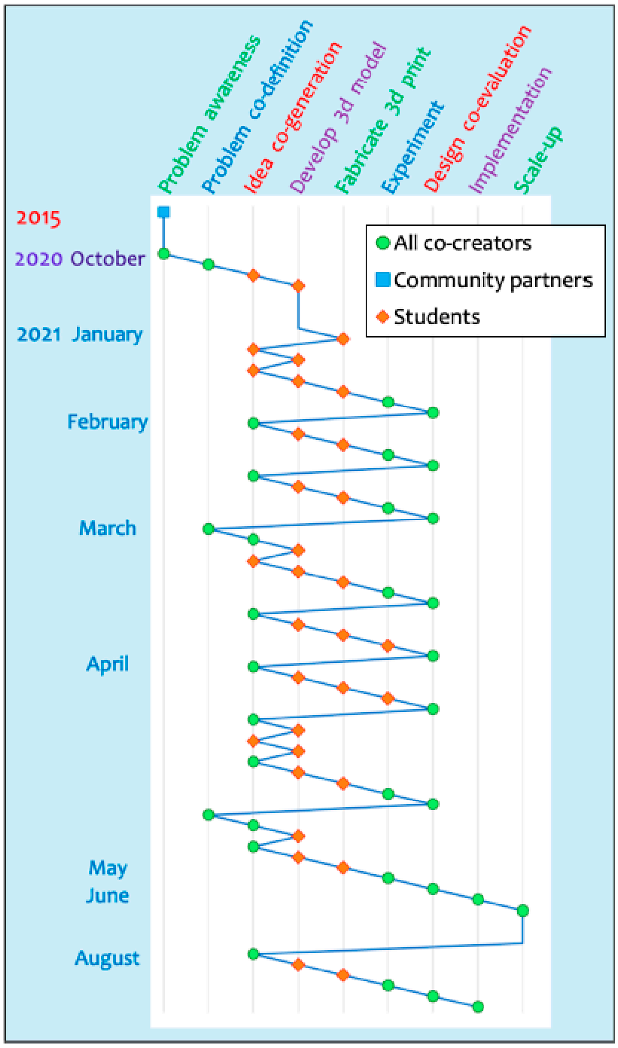

Figure 3. Design process. Steps taken throughout the iterative process delineated by co-creator.

As shown in Figure 3, after the initial two-week design project in October, the first large gap in the design process occurred while the students finished their fall courses. In January, the project resumed, and—over the next four months—15 CAD models were produced, and 10 prototypes were 3D-printed. The time between design cycles decreased in April once the students completed their classes. In May, the device was implemented for the community partners, and in June, production was scaled up to install the Mop Prop in 20 campus locations. The second large gap in the design process occurred from June until August, when a fracture in the part necessitated a final iteration.

Note that while 'Design co-evaluation' is defined as a distinct step, realistically evaluation was performed as micro-steps throughout the process. Ongoing evaluation is evident in Figure 3 where some CAD models were not 3D-printed, and some prototypes were not acceptable for experimentation. The 'Design co-evaluation' step was formally defined as the period when all co-creators were present to make decisions. These informal, unstructured meetings occurred when a design decision was required and lasted approximately 30 min. All co-creators contributed to the conversation, experimented with new prototypes, and proposed iterations.

This highly iterative process was possible due to the inexpensive prototyping costs. Numerous iterations were necessary to ensure that the device was strong enough to hold the mop and steer the bucket while also allowing the mop to pop out easily when pulled. Additional iterations were necessary to refine the thickness of the walls, the location of holes, and the angle of the shape.

The students were involved in all of the steps except for the initial ‘problem awareness’ step, which was identified by one of the community partners five years before the project began (denoted with a blue square). The level of collaboration of the community partners increased throughout the project, as initially most of the ideation was completed by the students (denoted with a red diamond) with community partners providing the bucket for testing. The steps quickly became more participative to include all co-creators (denoted with a green circle), as community partners started suggesting ideas such as changing the angle and strengthening walls. Not only did the community partners’ participation in decision-making increase but they also began to initiate action (two key actions for participatory design as defined in [26]). Co-design began to occur because the students became more collaborative, inviting feedback and design ideas, and the community partners became more invested in the design.

5. Interview Results: Community Partners’ Perspectives

The experience of the community partners throughout the design process is presented in their own words from the recorded accounts before and after the design was implemented. Rather than presenting these accounts in a narrative form, a thematic analysis was performed to highlight the commonalties and differences in their experiences. During the two interviews with community partners, five themes emerged from the coded transcript data: (1) emotional effects, (2) physical and mental effects, (3) productivity, (4) safety, and (5) job satisfaction. These themes are present in the data before and after the device was installed. The results are presented first as the perspectives from before the device was installed, then as experiences after the device was installed, and lastly as an examination of the impacts throughout the design.

Table 1 documents excerpts linked to the five themes about the community partners’ experiences before the device was installed. Regarding the emotional effects on the community partners before the device was installed, both community partners reported feeling anxious and worried due to the unpredictability of the mop handle. One community partner (B) described the problem as initially a pet-peeve that turned into a large frustration that they experienced for many years. The second community partner (A) was not consciously aware of the problem until the project was proposed, at which point they realized they were unconsciously worried while moving the bucket. Community partner B disclosed having bodily pain connected to the problem, while community partner A theorized that such pain might develop in the future through the repetitive motion of lifting the bucket with their foot to travel over bumps. In the interviews, both community partners demonstrated the physical maneuvers that each developed to move the bucket over thresholds and bumps. They both expressed their concern for the safety of the people who use the building, as they were worried that students and staff might be struck with an errant mop. They both described a range of emotions such as frustration, anger, stress, and anxiety towards the situation, and they both reported that an elevated degree of focus was required to use the mop bucket assembly. They both feared that the mop handle could damage equipment in the labs or hurt someone passing by, thus acknowledging a safety concern. Both community partners expressed a desire to perform their jobs well and felt they were inhibited from completing their job as efficiently, safely, and effectively as they would have liked to because when the mop would fall, water would spill out, and the community partners would have to clean up a new spill. Accordingly, their productivity was diminished. Community partner B compared the situation to a ticking time bomb that could explode at any moment due to any wrong movement. Before the community partners were asked to participate in the co-design experience, there was a mutual feeling of being belittled, either because the problem continued for a long time despite requests to resolve it or because they felt like they had to apologize to people walking by for simply doing their job.

Table 1. Community partners' experience before the device was installed. The table is dived into major themes, subthemes, and corresponding community partner excerpts.

Themes	Subthemes	Excerpts
Emotional effects	Low-confidence and anxiety	"I think every time [I used the mop bucket] was the worst memory because it was it's a product that I should be working at ease."
	Anger	"I felt it was something that should have been in place during the manufacturing of the bucket to alleviate all this frustration and anxiety of having to be reaching for a mop handle and reaching over again for a mop handle."
Physical and mental effects	Annoyance and physical pain	"Yeah, it's just frustrating by the time you're reaching three or four times a day or during the week, then I was going home with neck pain and shoulder pain."
		"Before, it was always on my mind"
	Unaware and unaffected	"It wasn't something like you're like losing sleep over this, [or] like there's an issue with this."
Productivity	Slow process	"I can't push the bucket as fast [as now]"
		"You lose more time because you're missing out on the job you're doing and it's a make work project [to clean up the water you spilled when the handle fell]."
Safety	Dangerous	"It could be a mess for safety if somebody came and slipped on it..."
Job satisfaction	Feeling of being unheard	"I did it over the years with different supervisors that it was a problem and asked if there could be some attachment or something that could be made or attached to the ringer and I was told it would cost too much money . . . to the university to have one on all the buckets on the campus, and it was dropped."
	False guilt	"We would find ourselves apologizing for doing our job"

After the device was added to the bucket, the community partners reported a high degree of satisfaction, as shown in the excerpts in Table 2. Community partner A (who was not aware of the problem beforehand) said it was a remarkable change that they were able to help create and were now able to reap the benefits. The anxiety and fear of hitting someone or something with the mop was alleviated. Both community partners expressed an increase in overall confidence and job satisfaction. The physical effects and mental stress of the problem subsided, and the community partners reported being able to complete their tasks faster and safely. Their efficiency improved because in order to clean spills quickly, the community partners are required to keep the mop bucket close while performing other tasks; the ability to move the bucket faster (without fear of dropping the mop) results in a faster completion of other tasks.

The community partners reported that the design process brought enjoyment and excitement to their jobs as they keenly anticipated each new iteration and working together with students. Community partner B provided the following account: "I was excited every time you guys came in and as we're working with these new prototypes." The partner includes themselves in the design with the term "we're" and later compliments the students on their professionalism and transparency throughout the process. Community partner A described how they influenced the design: "I like to be able to say the angle or when you were going to put it on the top of the bucket." They also described how their feedback was regularly elicited.

The community partners expressed positive impacts of the design experience, including the creation of a safer environment, a reduction in stress due to injuring someone, and satisfaction from being involved in the design process. Additionally, they explained how they now felt empowered to bring up other job-related problems that they experienced with peers and supervisors because the Mop Prop project originated with one of the community partners and the problem was effectively solved. They also demonstrated pride in being partners in the design, specifically when pointing out the design to students and staff walking by, describing how they were involved. The improved bucket design positively impacted the community partners, and the experience of becoming co-creators in the design process was additionally impactful.

Table 2. Community partners' experiences after the device was installed. The table is dived into major themes, subthemes, and corresponding community partner excerpts.

Themes	Subthemes	Excerpts
Emotional effects	Decrease in anxiety	"Once I put [the device] on it, you don't have to worry about it again."
		"Just the worry of it [mop falling], having to be focused on it."
		"I don't gotta worry about running into a screw or nut or bolt and if the bucket jolts, the handle's not going to flop over the place so with having the Mop Prop [device]."
	Decrease in fear	"You realize the anxiety that you might not have shown or spoke about after you put it on."
	Increase in confidence	"We can eliminate this problem"
		"But if something does arise, I would bring it to your attention"
		"[Be]cause you're a little bit more confident where you can move around right"
Physical and mental effects	No additional physical pain	"I got no neck pain, I got no shoulder pain, I got no stress, no anxiety."
Productivity	Ability to work faster	"So, it's a little bit easier now to zip around and not worry about hitting the dean on the head"
Safety	Safer than before	"It could be a mess for safety if somebody came and slipped on it..."
Job satisfaction	Less stressful	"I don't have to be thinking of coming to work and thinking, oh my goodness, I wonder how many times today the mop handle is gonna hit somebody or flop it in the bucket on me"
	Excitement and engagement	"I was excited every time you guys came in and as we're working with these new prototypes"

Table 3 lists the positive impacts that the community partners discussed during their interviews, such as solving a problem that was identified by one of the community partners. The table also differentiates whether each impact could be achieved through traditional designer/end-user methodologies or through more inclusive co-design methodologies. For example, the community partners' feelings of empowerment are primarily the result of contributing to the design in a co-design process, but an increase in speed and efficiency could result from any effective design methodology. Arguably, however, the design achieved through co-design is better suited for the community partners than a design created without the input of the co-creators, so the level of impact could be increased through co-design. The assessment as to whether each impact is unique to co-design was determined by the authors.

Table 3. Impact of co-design for community partners. Table distinguishes between whether the impacts identified by community partners are unique to co-design or could have been achieved using traditional design methodologies.

Impact	Traditional Designer/End-User Methodology	Co-Design Methodology
1. Solving a problem they identified in the workplace	x	x
2. Increase in speed and efficiency in job activities	x	x
3. Decrease in emotional and physical anxiety	x	x
4. Decrease in fear of breaking objects or hitting people	x	x
5. Empowered to discuss other problems pertaining to position		x
6. Passion towards job		x
7. Confidence in job		x
8. Pride in participating in co-design experience		x

6. Discussion

The first research question to document which stakeholders were involved in each step of the design process was addressed through the case study and Figure 3, and a growing level of collaborative partnership was evident in the data. The second research question to relay the community partners' experience throughout the design process resulted in five themes with distinct experiences before and after the device was implemented. From the interview data, it is clear that the device had a positive impact on the community partners. This section: (1) discusses how both the level of co-design found in the case study and the experience of the co-creators align with the literature, (2) documents insights gained from the students, (3) offers suggestions for similar pedagogical implementations, and (4) provides potential limitations of this research.

Through the interviews, the community partners discussed the ideas they provided, how frequently they gave feedback, and their appreciation for being integrated into the design process. Throughout the design process, the traditional design model quickly became more participatory through co-design as the students recognized the contributions of the community partners and the community partners began to feel like partners and co-creators in the design process. Comparing the participation of co-creators to Scott and Mazzurco's [26] framework, all co-creators were involved in decision making and collective action, but eventually the community partners began to initiate action and act as partners rather than end-users, mirroring the collaborative approach found in [18] as opposed to a vertical approach. The community partners were empowered to increase their role as designers through regular interaction with students, which was likely because the community partners saw the potential for a real solution and an openness to their feedback, as documented in [5]. Because the students came back after the initial design course ended and continued to iterate the design, the community partners were able to trust that the engagement of the students would result in a design, and thus, it was worth their time and energy to participate in the process. It was apparent in the interviews that the community partners trusted the students' determination to work towards a solution and openness to work together.

As documented in the literature, empathy helped the designers to better understand the problem [7], but what is unique to this co-design experience is that the four co-designers demonstrated empathy for each other. The students better understood the emotions and needs of the community partners, and the community partners empathized with the students' desires to produce a functional design and further their design skills. Engaging in empathetic design resulted in a better design.

For the students, an insight from the experience is that co-creators can be found everywhere. The community partners were working in the engineering building for years, experiencing this problem and waiting for someone to help them solve it. When the students initiated a conversation with one of the community partners about their job experience, this problem was immediately raised, and the co-design process began. As found in the literature [23], an everyday experience was turned into inspiration for a project. Projects can be found anywhere, especially locally. The first step to encourage co-design is to ask questions and empathize with the person.

The second insight that the students had is that they are able to help others, even with their limited experience. They were only two months into their degree program when the project began, and though they were only beginning to develop technical skills, after interacting with the community partners, they felt compelled to participate. Community partner B stated the following: "I really think that [for] engineering students, it's an obligation." This community partner was waiting to be asked to participate, hoping students would ask. As demonstrated in the literature, it is because of their differing experiences, skills, knowledge, and needs that the co-creators worked effectively together [19] and the students realized that they could provide support, even with their limited technical abilities.

The third insight of the students is that frequent and respectful communication is key in co-design. Weekly meetings became essential to ensure the co-creators were equally included in the process to provide their opinions, design ideas, and evaluations. While the project began as a designer/user methodology, it became apparent that in order to produce the most effective design and to incorporate the experience and knowledge of the community partners, a co-design process was required, thus transforming end-users into co-creators. The increased time commitment confirms one of the barriers related to engaging community partners in the design process [8,9], but because all co-creators were willing to spend the time, the result was a successful design [20].

From the instructor's perspective, first, to ensure similar co-design experiences are possible for future student design projects, commitment, trust, and collective partnership are necessary for both students and community partners, and these aspects are built over time. Realistically, in a class environment, it is difficult to build a relationship during the structured time allotted for a particular project [8,9]. However, long-term engagement with regular deliverables can be used to build trust and show engagement between both students and community partners. To ensure a successful partnership, the expectations of community partners should align with what the project can reasonably produce [12]. Exercises coaching students on how to invite and incorporate feedback can aid the development of more inclusive design. At a minimum, encouraging students to work with community partners as opposed to developing hypothetical problems will allow them to empathize with the end-user [22], which can help them to engage with the project until a solution can be found. Engaging in participatory design can also challenge traditional power structures through social justice discussions and empowering community partners [6].

Second, educators and researchers can work to address the lack of research documenting community partners' perspectives in design projects (as found in [5,13,14]). While a full research study may be excessive for all projects that include community partners, inviting community partners to complete project evaluations throughout the design process can shift a project from passive to participatory design [6]. While being considerate of the entire user experience (as in [25]), the act of soliciting feedback can also improve future projects and help educators and students to understand how the design experience could have been optimized.

Third, although the case study focused on a particular design experience, community partners can be integrated into many forms of project-based learning. A homework assignment to demonstrate a particular skill that has been gained can be enlivened with the participation of a community partner presenting the real-world problem. For example, a statics course focused on equilibrium equations could have a community partner who has a certain piece of equipment that keeps falling over. Students could calculate an aspect of the device that should be changed (larger base or shorter height) and be expected to provide calculations to support their decision.

One limitation of this study is that the community partners were the participants in question 2 rather than the co-authors of the paper. For a more holistic co-design experience which extended through the research, the co-designers could have interviewed each other. Out of respect for the community partners' time and in recognition of differing areas of expertise, the students and instructor took an initial step to document the community partners' experience, though we acknowledge that future steps can be taken for a more inclusive design and research experience. Lastly, the hierarchical structure of a university could have compelled the community partners to provide responses that they perceived the students and instructor wanted to hear rather than their actual beliefs, similar to the imbalanced power structures documented in [7]. It is clear in the interview data that at least one of the participants demonstrated an eagerness to praise the students and the design, however, that participant also proactively showcases the device to anyone who enquires about their mop bucket, demonstrating a genuine pride in participating in the design process. Additionally, the interview questions were open-ended to avoid leading the participants towards a specific answer.

7. Conclusions

Utilizing a co-design methodology, two students and two community partners designed a device that improved the community partners' job performance, confidence, and emotional, mental, and physical health. One community partner commented, "I got no neck pain, I got no shoulder pain, I got no stress, no anxiety." Through a review of design artifacts and files, an iterative design process was documented and revealed an increasing level of collaboration between co-creators. The community partners' experiences were documented through a qualitative study to provide data for future design research. The community partners felt empowered to be included in the co-design process, which is evident each time they demonstrate the device to people in the building.

By empathizing with the community partners, the engineering design students engaged beyond the initial course requirements to design a product that was implemented in 20 locations across campus. The community partners' passion and willingness to share their time and expertise through a collaborative project captured the attention of the students and provided ongoing motivation, which, in turn, helped the community partners to become more invested in the design. For this project, employing a co-design process resulted in a better product and a more enjoyable experience for the co-creators.

Project-based learning helped the students to practice their presentation, CAD modelling, and design skills and develop empathy, determination, and collaborative skills. These findings can inspire engineering educators to incorporate project-based learning into their courses with community partners and can encourage researchers to document the perceptions of community partners in design projects.

Author Contributions: Conceptualization, methodology, validation, interviewing, and data analysis: L.M. (Liam Murdock) and L.O.; writing—original draft preparation, transcription, and product design L.M. (Liam Murdock); writing—review and editing, supervision, project administration, funding acquisition, L.O., writing–review and editing and product design L.M. (Luke McCarvill). All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding, but was funded by an internal research grant from the University of Prince Edward Island.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Research Ethics Board of the University of Prince Edward Island* REB# 6009235 on 5 August 2021.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: For the privacy of the participants, interview data are not publicly available. Interview protocols are available by contacting the corresponding author.

Acknowledgments: We are grateful for the time and expertise of the co-creators in this project, as well as for the support from university management in the implementation of the device across campus. Lastly, we offer thanks to the person who donated their time to 3D-print the many iterations.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The semi-structured interview protocol is as follows:

Part 1: Data/Demographics:

1. Name:
2. Years at UPEI:
3. Years as a custodian (anywhere):
4. Has Mop Prop been attached to your bucket
5. Roughly How long has the Mop Prop been attached to your bucket:

Interview:

6. Please describe your experience using the mop bucket before the Mop Prop was added. (Potential prompts as follows):
    - Do you have a specific memory regarding using the mop bucket?
    - How did that make you feel?
    - Did it fall frequently?
    - Do you think other custodians share this view?
    - How big of a problem was it?
7. Has the Mop Prop changed your experience with the mop bucket?
    - If so, how?
    - Does the mop still fall?
    - Are there new issues with it?
    - Does it change how you feel when you using it?
    - Specific advantages/disadvantages
8. Do you prefer the bucket/wringer with or without the Mop Prop?
9. Are there any changes you would make to the Mop Prop?
    - What would you like to see changed?
    - Are there other aspects of mopping that could be addressed?
    - Do you have any other issues with custodial equipment that you'd like to see changed/improved upon? (or the introduction of an accessory to fix such an issue)
10. What has been your experience overall with custodial equipment?
11. Is there anything else you would like to tell us?
12. Do you mind telling us how tall you are?

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