WIP: Introducing Students to Human-Centered Design in a Design for Manufacturability Course

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For the past 25 years, Leon Liebenberg has been engaged in engineering teaching, research, and community engagement. He was a professor of mechanical engineering at two South African universities (University of Pretoria; North West University), before becoming a higher education consultant in Switzerland where he worked with colleges of engineering and technology management. Leon is passionate about multidisciplinary research, particularly in the fields of energy engineering, biomedical engineering, and engineering education. His university research has focused on development of industrial energy-efficient technologies and cancer therapies using energy restriction methods. His published research works enjoy an h-index of 22. Leon’s first love is however for teaching. He co-developed and taught a unique freshman course on "Innovation", where students work in so-called "whole-brain" thinking teams when addressing technological problems. These helped show that innovation for a sustainable world can be maximised by the convergence of natural sciences, engineering sciences, and the arts. At the UIUC, Leon is a teaching associate professor and he is currently engaged in developing gamification platforms for use in the mechanical engineering curriculum. The intention is to promote deep learning and improved engagement of students in subject matter. Leon is collaborating with colleagues from various disciplines in this venture. He also founded the TechnoLab technology awareness facility for junior engineering students and for school children, where the learners work in small teams to solve problems using Lego Dacta and other didactic equipment. The TechnoLab model has been adopted by several South African schools since its inception in 1997. Leon also founded the Space and Aviation Challenge for school learners in South Africa, which aimed at demystifying the aeronautical engineering profession. The Challenge was annually presented for several years in collaboration with Nasa’s Dryden Lab who offered the first prize for a learner to attend Space Camp USA. Leon teaches a variety of subjects, including: Innovation; Statics; Dynamics; Thermodynamics; Fluid Mechanics; Design for Manufacturability; Machine Design; Heat Transfer; Aerodynamics; Aeronautics; and Advanced Heat and Mass Transfer. Leon holds doctoral and master’s degrees from Imperial College London and from the University of Johannesburg. Leon and his wife enjoy meeting people, engaging with local communities, reading, photography, hiking, cycling, and spending time with their cats.
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Introduction

This work-in-progress paper describes the implementation of an activity that introduces human-centered design to students in a Design for Manufacturability course. It explores the TAs’ experiences of implementing this activity to provide insights into the challenges of teaching human-centered design in engineering classes and to seek ways to overcome these challenges. It also examines the impact of the activity on students’ understanding of the role of human-centered design in design for manufacturability in engineering. The paper concludes with guidelines on how to modify the activity for future implementations in the course.

What is Human-Centered Design?

Human-Centered Design (HCD) is an interdisciplinary, problem solving approach that identifies the unmet needs of a population in order to collaboratively develop solutions. This approach puts humans in the center of the design process and seeks to understand them, collaborate with them, and involve them in the design process in order to make products or services useful, usable, and desirable [1]. To do so, human-centered design involves the implementation of practices such as observing what people do, interviewing people, brainstorming and communicating ideas, and building and testing prototypes [2]. Across all educational settings, researchers argue that engaging students in human-centered design experiences can help them address real world problems and develop human-centered, experimental, collaborative, metacognitive, communicative, and creative mindsets [3]–[5].

Why Human-Centered Design in Engineering?

While traditional engineering curricula emphasize technical and analytical problem-solving skills, in the last few decades attention has shifted toward engineering design skills developed through project based or experiential learning [6]–[12]. Broadly speaking, this shift attempts to address the perceived disparity of engineering skills developed in the classroom as compared to those needed by industry [13]–[16]. This is exemplified by the differences of ‘open-ended’, ‘ill-defined’, or ‘real-world’ problems encountered in design as opposed to the closed-form problems which often appear in problem sets of engineering textbooks [17]. While often accepted as a central part of engineering practice, many engineering educators face significant challenges when teaching design. Researchers have long been aware of the need for descriptions of design theory and practice which help to mitigate the challenges of teaching and learning engineering design and serve as enabling tools for engineering designers and researchers [10], [12], [18].

Human-Centered Design has risen to prominence as an approach that enables designers to clearly understand the unmet needs for which they are designing and to develop solutions that address these directly [2], [19], [20]. Despite this popularity and utility, human-centered
consideration faces resistance in engineering spaces which often seem to prefer quantitative, rather than qualitative objectives. By integrating engineering experiential learning (e.g. manufacturing labs, product dissection) with human-centered design practices (e.g. empathizing with stakeholders, using narrative methods to share ideas and get feedback) students can develop skills that expand on those gained from traditional engineering problem sets, and more closely resemble real-world engineering practice. The ABET accreditation criteria for engineering programs outlines required student outcomes which prepare graduates to enter the professional practice of engineering [21]. We believe human-centered design activities can directly benefit at least the following three criteria, quoted here:

- **An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors**
- **An ability to communicate effectively with a range of audiences**
- **An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts**

HCD provides a basis from which engineering students can understand and respond to specified needs. In HCD projects, students use interview and observation in order to gain a broad understanding of existing problems, unmet needs and opportunity areas which enables the proper discovery and consideration of relevant factors. Throughout the design process, students must clearly and effectively communicate their insights and justify their decisions to seek confirmation and validation from the various stakeholders involved. The impact of design decisions can be seen by working directly with these stakeholders to testing assumptions and concepts as they are developed, allowing students to make informed judgments. However, these benefits rely on the successful implementation of human-centered design activities in engineering classes. This often depends on the graduate teaching assistants (TAs) who lead discussion or laboratory sections. This work-in-progress paper describes the implementation of a human-centered design activity that introduces human-centered design to students in a Design for Manufacturability course. It explores the TA’s experiences in implementing this activity and the impact of the activity on students’ understanding of the role of human-centered design in design for manufacturability in engineering.

**Methods**

**Design**

This study is part of a design-based research initiative that is led by a newly established design center, the Siebel Center for Design, at a large Midwestern University. The center coordinates with faculty members on campus to integrate human-centered design in their courses. The center then follows a design, implement, and evaluation cycle [22] to understand and evaluate the integration process in order to inform future iterations of integrating human-centered design in courses. This study used a complementarity mixed-method design [23] to a) understand the experience of the teaching assistants as they implemented an introductory activity of human-centered design in a Design for Manufacturability course and b) examine the impact of the activity on students’ understanding of the role of human-centered design in design for manufacturability in engineering.
The Context of the Study

The study took place in an undergraduate engineering course that introduced 190 students to Design for Manufacturability tools and methodologies. In Fall 2019, there were 15 laboratory sections of this course. Each section had 12 to 15 students and was facilitated by two graduate teaching assistants. TAs first received a one-hour training session on human-centered design from a Senior Design Strategist at the Design Center, and a one-hour training session on storytelling techniques from an industrial enterprise and systems engineer. In the first week of laboratory sessions, the TAs implemented an activity that engaged students in redesigning a staple remover using a human-centered design approach. In the second week, students communicated their redesign strategies and outcomes to their peers using storytelling techniques by creating a poster and presenting it in lab. In this implementation, students’ work was not assessed for merit; however, the TAs provided the students with constructive feedback on their work during both weeks.

Students were given a laboratory manual with an introduction to HCD concepts and a basic procedures for them to follow throughout the activity. This information was also included in the presentation slides used to introduce the activity and provide prompts and instructions for each step of the activity. A supplemental video was also made available to TAs who preferred to use this resource to introduce students to HCD. During the training session, TAs were provided copies of the manual given to students and the trainers walked through the presentation and activity while providing instructional guidance.

Participants

The participants in this study were two TAs and 115 students (1 Freshman, 90 Sophomores, 15 Juniors, 9 Seniors) that were registered in the course for Fall 2019. Both TAs were graduate students pursuing their graduate studies in engineering. One TA had experience teaching engineering laboratory courses while the other did not.

Data Collection Procedures

In the first week, one researcher observed the implementation of the activity in two laboratory sections. The laboratory sections were selected based on the TAs’ willingness to participate in the research study. Two researchers interviewed the two TAs of these sections. In addition, an online questionnaire was sent to all students registered in the course. The questionnaire included the following six questions:

1) What was your experience with Human-Centered Design before this activity?
2) By participating in this activity, what did you learn about the role of Human-Centered Design in Design for Manufacturability?
3) What was the most challenging part of the activity?
4) What was the most enjoyable part of the activity?
5) Did this activity influence your laboratory experiences during this course?
6) Did this activity influence your views of Design in Engineering? If yes, how?
Data Analysis

Notes from the researcher’s classroom observations were used to describe the implementation of the activity in the laboratory sections. The interviews with both TAs were transcribed. Two researchers examined the transcriptions. Three themes emerged from examining the transcriptions (see Table 1). Descriptive statistics were used to analyze students’ responses to the questionnaire. Responses to open-ended questions were coded by theme, and the most frequently represented themes are discussed. When applicable, a keyword search was used to identify responses which may correspond to a given theme.

Table 1: Emergent themes from interviews

<table>
<thead>
<tr>
<th>Theme</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Benefits</td>
<td>Statements or phrases about the possible benefits of engaging in the HCD activity on students’ course experience.</td>
</tr>
<tr>
<td>Challenges</td>
<td>Statements or phrases about the challenges that teachers or students face when engaged in the HCD activity</td>
</tr>
<tr>
<td>Suggestions</td>
<td>Statements or phrases about possible ways to improve the implementation of the HCD activity in future courses.</td>
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Results

The Implementation of the Activity

Based on the researcher’s classroom observations, in week 1, the TAs introduced human-centered design using a presentation and accompanying activity guide prepared by a Senior Design Strategist from the Design Center. While introducing human-centered design, one TA memorized and recited a definition provided in the training session, while the other reframed it in their own words. A short video was also used to familiarize students with some core activities of human-centered design, such as interviewing and ideating. Students then worked in dyads or triads to complete an activity aimed to simulate an HCD process while TAs facilitated discussions between group members as needed. Students were instructed to interview each other about their experiences related to staplers, staple removers and other paper fasteners. These interviews were repeated in several rounds to allow for reflection. Students often needed additional guidance from TAs to find new questions and perspectives to better approach the problem. Students were then instructed to document their understanding of how staplers and staple removers are commonly used. Then each group was given a staple remover, a set of tools and personal protective equipment, and was asked to disassemble the staple remover while describing their actions, as in think-aloud protocol. TAs encouraged students who were not engaged in disassembly to observe, ask questions and take notes about the process and experience of disassembly. During this process, TAs supervised students to ensure their safety and provided suggestions for questions to ask or things to consider (e.g. recyclability, safety, usability, repairability). Groups then interviewed the team member who was responsible for disassembly and synthesized their findings to come to a “point-of-view” statement describing the needs of a specified end-user. Students quickly sketched some ideas in preparation for the next lab. Then, the TAs led a brief discussion reflecting on the activity. The activity is
intended to fit in a 2-hour lab session and was completed in approximately 1 hour and 30 minutes, allowing students additional time to prepare for the following lab.

The researcher did not observe the lab sessions in week 2. However, during the interviews, TAs were asked to describe the activity in week 2. The TAs reported that students brought sketches from the previous week and were given 45 minutes to work with their group to come up with a story representing their redesign and create an accompanying poster. The TAs mentioned the importance of this unstructured time, with one TA stating, “So this is one of the key things, I think the timing is quite right in terms of 45 minutes. They got a chance to actually do a lot of talking in a way that students could interact with other people openly and come up with a lot of creative ideas.” The other TA said, “they started to not only focus on course materials, they started trying to build up networks with other people within the same group or a different group, it’s kind of nice, it’s like during this lab, you can learn your materials from class, but also you can build up friendships.” After preparing their posters, each team presented their work.

Teachers’ Experience

**Benefits:** The analysis of the interviews showed that the TAs thought that the activity had two major benefits. First, it was a good starting point in the course where students began to practice disassembling products and think about redesigning them from a human-centered perspective. One TA mentioned “I think overall the activity is really a good start for students to think about human-centered design”. He adds “usually students design products using cool technology and it looks fancy; however, the design doesn’t have anything to do with people’s lives; they need to bring up human-centered design and start thinking what people’s problems are and start designing based on what those problems are”. The other TA said, “the activity is a nice starting point; before you really get to the course material, you can start with easier concepts or more practical concepts besides the theoretical concepts.”

Second, the TAs thought that the activity provided students with the opportunity to develop soft skills such as human-centeredness, creativity, and communication. One TA mentioned “I think the purpose that we implemented this activity is to improve the soft skills to be honest; just try to get them a little bit of creativity, kind of like thinking out of the box of the problem”. The other TA said, “The activity lets us cover some soft skills like communication and human-centeredness”.

**Challenges:** The analysis of the interviews showed that the TAs thought that the activity posed two major challenges. First, it was challenging for students to interact with each other and with the TA around the activity. One TA mentioned “I think the challenge is how to get the students to interact between each other”; the other TA said “the class environment needed to be more lively, more interactive, it’s really hard to break the ice”, this TA also mentioned that “students are just afraid to ask questions”. One reason can be that the activity was implemented in the first two weeks of the course. One TA mentioned “I think the students are little bit silent in the first week”. The other TA said, “I think we would have been better if the activity started on the second week because we would have been familiar with the students.”

Another challenge for the TAs was presenting human-centered design and emphasizing its relevance to what the students are doing in the course and facilitating the human-centered design processes among the students. One TA mentioned, “Another challenge was to influence or even talk to students about human-centered design and how it is important to what they are doing”; he adds “some of the students just don’t like the idea at all, they just come up with their own product, done!”. The other TA said, “When the activity started, every group started working and talking:
however, it was challenging to go to the groups and talk to them or intervene in their conversations”.

**Suggestions:** The analysis of the interviews also showed that the TAs suggested two major changes to the activity. First, both TAs suggested introducing an ice-breaker activity that sets the stage for implementing the human-centered design activity. One TA suggested sharing his own experience with human-centered design during the ice-breaker activity so “students can learn how human-centered design is relevant to what they are going to do”. Second, one TA suggested including a more challenging task other than disassembling a stapler remover. He also suggested providing students with more material in addition to paper so that “they can come up with a physical prototype of their product rather than just drawing it”.

**The Impact of the Activity on Students**

Responses to the online questionnaire were used to measure the impact of the activity on students. A total of 115 responses were collected (n = 115). Class standing and Major are shown in Figure 1A and 1B: 1 Freshman (1%), 90 Sophomores (78%), 15 Juniors (13%), and 9 Seniors (13%). Four engineering majors were reported, Mechanical Engineering (85%), Engineering Mechanics (10%), Industrial and Enterprise Systems Engineering (3%), and Electrical and Computer Engineering (2%).

In response to the question, ‘What was your experience with Human-Centered Design before this activity?’ 49 students had some experience with Human Centered Design (45%), 52 had no experience with human centered design (43%), and 14 provided an answer which was unclear (12%) (see Figure 1C).

Responses to the question, ‘By participating in this activity, what did you learn about the role of Human-Centered Design in Design for Manufacturability?’ showed that students view Human-centered design as an important part of Design for Manufacturability. This was indicated by responses such as, “It is very crucial to the design process” and, “I learned that it is critical to think about the problem rather than the solution when trying to innovate. The needs of human and customers is more important than what the engineers think is the need”. Responses also showed that students learned about the importance of human-centeredness and designing for unmet needs as indicated in the responses, “I learned the importance of designing for the user and not just for the client or company” and “I learned the process of designing around the needs of customers”.

Responses to the question, ‘What was the most challenging part of the activity?’ showed that students were challenged by the storytelling aspect of the activity. This was indicated by responses such as “I think the storytelling part was the most difficult, because we had to use a different part of our brain than we usually do in these classes” and “Coming up with a story that was both engaging and got an idea across.” Responses also showed that students found it challenging to come up with creative and novel ideas. This was indicated by responses such as “It was challenging to think of new ideas”, “Thinking of ways to innovate such a simple product”, “The most challenging part had to be actually redesigning the stapler, and “A stapler already has a very efficient design, to improve on it further was definitely difficult; this proved to be a great way to introduce the course.”

Responses to the question, ‘What was the most enjoyable part of the activity?’ showed that students enjoyed several aspects of the activity, including working creatively to come up with their story and working with their peers. This was indicated by responses such as “...thinking up a creative way to portray the story of the problems in the current design and how our redesign fixed
those; while it was pretty challenging, it was fun to think of different ways to convey that storytelling aspect”, “While I do think coming up with a story was difficult at first, it was a lot of fun to execute and then present. Other groups had really funny, good ideas and it was a good activity to practice our creativity”, and “Presenting our work to our classmates as well as seeing what ideas they came up with.”. Students also enjoyed the hands-on aspects of the lab such as drawing and disassembly. This was indicated by responses such as “I liked drawing”, “Taking the remover apart and analyzing potential design opportunities [sic]”

Responses to the question, ‘Did this activity influence your laboratory experiences during this course?’ showed that 64 students responded in the negative (56%), 43 responded affirmatively (37%), and 7 responses were unclear (8%) (see Figure 1D). Those who responded affirmatively said the activity helped to set the tone for the rest of the semester. For example, they mentioned “Yes; it set the precedent on how we should approach problems with the big picture in mind”, “I think it definitely got us to think more creatively during the labs, and also made us more comfortable with each other as a lab section, since we all came up with pretty funny and goofy posters.” Those who disagreed pointed out that other lab sessions had a different focus. For example they mentioned “No, to be honest I felt that they had nothing to do with each other because our subsequent labs had nothing to do with human-centered design; the focus was on learning about manufacturing processes and analytical skills.”

Responses to the question, ‘Did this activity influence your views of Design in Engineering? If yes, how?” showed that 82 students responded affirmatively (71%), 27 responded negatively (24%), with the remaining 6 responses unclear (5%) (see Figure 1E), e.g. “kind of”, “I’m not sure if it did or not”. Those who answered affirmatively mentioned designing for unmet needs and remaining human-centered. For example, they mentioned “Yes. It not only involves rigorous mathematics / physics applications and building [sic], but also considerations about the markets, human needs, environment, etc, as a whole”, “This activity did shift my view of design more towards something which is not necessarily aligned with ‘technological progress’, but can be more aligned with meeting needs” and “Yes; it made me a lot more aware of what my job is going to be for. In school, all we do are strenuous math problems and it's hard to see that there's a human connection behind that. But this made me realize that my job in the end will be to help humans.”
Discussion

This study explored the TAs’ experiences with an activity that introduced human-centered design in a Design for Manufacturability course. The study also examined the impact of the activity on students’ understanding of the role of human-centered design in design for manufacturability in engineering. Results indicated that the TAs thought that the activity helped the students think about disassembling and redesigning products from a human-centered perspective and provided them with the opportunity to develop soft skills such as human-centeredness, creativity, and communication. Results also indicated that the activity helped students view human-centered design as an important part of design for manufacturability and many of them (71%) reported that this activity has influenced their views of design in engineering and shifted them towards designing for unmet needs and remaining human-centered. Also, students enjoyed several aspects of the activity, including working creatively to come up with their story, collaborating with their peers, and presenting their work. They reported that the open and collaborative nature of the activity set a tone for the rest of the laboratory sections of the course. These results suggest that the TAs had
a positive experience implementing the activity which had a positive impact on the students’ experience and their understanding of the role of human-centered design in design for manufacturability in engineering.

In addition, the TAs reported that it was challenging for students to interact with each other and with the TA around the activity. To overcome this challenge and to facilitate discussion, the TAs suggested adding an ice breaker before students are asked to interview each other. Future iterations of this activity can include an ice breaker activity that can engage students in getting to know each other before they actually start working on the activity. In addition, future iterations of this activity must be accompanied by TAs’ preparations that do not only help the TAs in effectively presenting human-centered design concepts to students, but also in effectively facilitating discussions between the students. This has the potential to respond to suggestions from both TAs for the need of further preparation to implement the activity more effectively.

Both the TAs and students pointed out that the fluidity of discussion and students’ eagerness to interact may also be influenced by the subject of the redesign activity. In this activity, students worked to redesign staple removers, which are relatively simple in construction and working principle. Students described the staple remover as, “simple” and “mundane” and had difficulty coming up with novel ideas for a redesign. This simplicity has some benefit as it limits the scope of the task and reduces the cost of materials (remember that students disassemble, and in many cases destroy the product during the activity). A mundane object which is redesigned in an innovative way will demonstrate the strength of the design method but may not inspire a novice to attempt it. The staple remover was chosen because it was suspected to be familiar, and therefore give students more to discuss during interviews. However, it is possible that a more interesting, but unfamiliar object may evoke more lively and fruitful discussion in future implementations of the activity.

Future iterations will include more detailed assessments of students’ work. To assess students’ work, a rubric to score the students’ stories and posters will be developed. It will include aspects that can prompt students to reflect on and consider the HCD aspect of their design, story and poster. Additionally, the connection between HCD in this lab activity and the remainder of the course will be strengthened. In existing manufacturing labs, this would include more reflection prompts on the use of HCD in manufacturing. Currently, student teams work to complete a series of mini-projects in which they disassemble and redesign a discarded product while addressing a design-for-manufacturability aspect. In doing these redesigns, students must interview stakeholders, which could be users of products or designers of such products. Students must necessarily empathize with the stakeholders, reflect on their interviews, and incorporate design ideas in a co-creative manner. The successful integration of HCD and narrative pedagogy with project-based learning should help transform a design course into a series of engaging learning experiences.

Finally, it is noteworthy that this initial implementation of the lab activity represents a first prototype in an iterative design-based research process. As such, this activity was intended to provide initial feedback and have minimal disruption of the existing course structure. This provided constraints which may be useful in determining the necessary conditions for subsequent iterations. For example, time available for TA training was naturally limited. In anticipation of this limitation, the activity was designed to be self-explanatory so that the main responsibility of the TAs was to ensure that students understood the instructions and remained on task and on schedule. This approach was intended to familiarize students with basic HCD concepts which are later explored and used to a greater extent (e.g. in courses taken in the following semester).
Conclusions and Implications

Overall, it seems that both the TAs and the students had a positive experience with the activity described in this paper. Moreover, the activity had a positive impact on the students’ experience and their understanding of the role of human-centered design in design for manufacturability in engineering. The TAs and students reported specific challenges that can be resolved in the future implementations of this activity. Findings from this work facilitates the integration of human-centered design in engineering education by providing insights that can inform the design and implementation of human-centered design activities in higher education engineering courses.

References


