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Engaging Students in Engineering Design through Low-vision Simulations

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Design through empathy: how low vision simulators can be used to engage students in better design solutions (Academic Practice/Design Interventions)

INTRODUCTION:

One of the objectives of a first-year engineering design course is to engage students in a real engineering design project. The team project typically requires students to design a prototype and experience the engineering design process. An advantage of first-year projects is they allow teams to practice skills and learn content related to the classic engineering disciplines (for example, solar powered cars for electrical engineering, egg drop for biomedical engineering, bridges for civil engineering) but can fail at captivating the interest of all students. A student who wishes to study chemical engineering or material science might feel disconnected from the project because the content area does not seem to apply to their future career. In addition, the projects might not connect with underrepresented students. Maintaining interest in the major is important for engineering programs concerned with improving retention rates.

In traditional design-based courses, it is common practice to observe engineering teams gravitating to a final solution without deeply understanding the nature of a problem. Beginner engineering students tend to spend less time in the problem scoping phase of the design process and forget to consider the true needs of the user [1], [2]. Students from outside the engineering fields or high school students may have never engaged in the engineering design process so they quickly fall into a trial and error approach. In each of these cases, the interest to develop an elegant solution through a systematic design process approach does not come to fruition because the students never develop a connection with the problem they are trying to solve.

An alternative to creating more inclusive projects is to step away from the engineering content areas and use project-based learning (PBL) with an emphasis on themes of social justice, service learning and the needs of people. As a pedagogical tool in the engineering classroom, PBL has shown to have many benefits including student engagement, diversity and learning [3]. These themes can connect with many students especially when the experience allows for the opportunity to “step into the shoes” of the affected user and later possibly interview at least one user. Research on capstone design courses shows that periodically meeting with clients raises student expectations and holds them accountable for meeting the goals [4], [5]. The development of empathy drives teams to go through the design process and allows students to remain engaged in the entire process.

Design Thinking: In the design field, a human centered approach is sometimes used to build empathy for the end-user of a product. It allows the designer to intimately understand the problem from the user’s perspective and think about the real needs and capabilities of the user through each step of the design process [6], [7]. In the classroom, one can apply human centered design to help students become engaged in the problem. In industrial design, thinking about the needs of the user guides design and in biomedical engineering working with a client who has a disability spurs students to meet their objectives. Hynes and Swenson call on engineering educators to consider the humanistic side of engineering and look at problems from the perspective of their users [8].

Disability simulations are often used to give people a sense of what it feels like to live with decreased physical ability or a visual impairment. Empathic modeling through low vision goggles can give participants a new perspective on how the loss of a sense can drastically change their awareness of an environment or a task [9]. Often used for training teachers of the blind or helping family caregivers adapt to a new living situation, simulations are intended to promote empathy. This is important because sighted participants will often break the misconception that blindness means complete darkness and in addition they become aware of the variety of vision impairments that exist. On the other hand, a low vision simulation has to be introduced with the understanding that it can only mimic a temporary experience of blindness which can be very misleading if not given the appropriate context. Research shows simulations often fail at recreating the life-long experience of living with blindness including the adaptations one makes to live in visual world [9] - [12].

In four sections of an introductory engineering design course at The College of New Jersey (TCNJ) students were asked to design a product to make a dorm room more accessible for students with vision impairments. To increase engagement, students participated in a low vision simulation to experience what it feels like to have a vision impairment. The class followed the steps of a human centered design process lesson plan: research, participation in a low vision simulation, development of multiple solutions, evaluation, building a scale model of the dorm room and their product, and delivering a final presentation [13]. It is important to note that the final deliverable of the project was a scale model of the room with a prototype of their innovative design placed inside the scale model. To measure the effect of the low vision simulation, the degree of the intervention was changed in each of the four course sections: 1) blindfolds only, 2) low vision goggles and blindfolds, 3) low vision goggles, blindfolds and a training session about vision impairments, 4) low vision goggles, blindfolds, a training session and an interview with a blind student. The effect of each intervention on the quality of groups' final designs are analyzed in this paper.

This study measured the effect of the type of low vision simulation on the quality of the final prototype. The authors predicted that groups who participated in the most in-depth simulation would be more invested in the project and therefore exceed the technical criteria and user requirements of the problem statement. By attending a training session and interviewing a person affected by blindness they would have a better understanding of the problems faced by the blind and work to improve the quality of their final prototype.

METHODS:

Student population: The IRB approved study recruited participants from four sections of a Creative Design Course at The College of New Jersey (TCNJ). This course fills a campus-wide liberal learning requirement of visual arts so students from all majors and grade level are

Table 1: Class participation by gender.

Students	Case 1	Case 2	Case 3	Case 4	Total (%)
Female	10 (45.5%)	9 (40.9%)	3 (12.5%)	16 (76.2%)	38 (42.7%)
Male	12 (54.5%)	13 (59.1%)	21 (87.5%)	5 (23.8%)	51 (57.3%)
Total	22	22	24	21	89

represented in the population. The course introduces students to creativity, the engineering design process, human centered design, the elements and principles of design and design thinking. The class meets twice a week in class periods of an hour and 20 minutes.

Collection: Participants were provided a description of the study one week before the low-vision simulation. The investigators visited the class and described the study to the students. Consent forms included a written description of the study and the safety protocol. Students who gave written consent for participation were over 18 years of age. Across the four course sections, the total male and female participation was 57% and 43%, respectively, as shown in table 1.

Design activity: In groups of four, students were asked to design a product for a freshman dorm room to make it more accessible for students with vision impairments [13]. In other words, the product should make a typical room activity easy to be completed without the need of normal vision. It should also aspire to meet universal design principles so it could be used by anyone. The activity followed a human centered design approach where groups researched the problem, participated in a low vision simulation, developed multiple solutions, performed an evaluation, built a scale model of a dorm room to showcase their product, and presented their final design to the class.

The low vision simulation occurred in an unfamiliar dorm room or classroom. A trained professional from the Center on Sensory & Complex Disabilities demonstrated how to operate as a guide for someone that is blind or vision impaired. After the demonstration, half of the students in the course section took the role of the sighted guide while the other half wore the goggles or blindfolds. Students were instructed to navigate through the room and perform the daily tasks they perform on a typical day; wash their hands, sit at a desk to study, use the microwave, sort items, etc. After 20 minutes, students switched roles and traveled to a different room to give their partners the same experience.

There were four versions of the low vision simulation and each one corresponded to each class section (Table 2). Case 1 involved only blindfolds. Case 2 involved blindfolds and thirteen different low vision simulator goggles (Fork in the Road Vision Rehabilitation Services, LLC, Madison WI). The vision impairments simulated by the googles are tunnel vision, central scotoma, diabetic retinopathy, hemianopsia, and blur/glare with a low visual acuity. Case 3

Table 2: Description of the low vision simulation interventions (4 cases).

Case 1:	Blindfolds only (dormitory)
Case 2:	Simulators and blindfolds (dormitory)
Case 3:	Training session, simulators and blindfolds (classroom)
Case 4:	Training session, group interview, simulators and blindfolds (dormitory)

involved the simulators along with a 30 minute training session conducted by the assistant director of the Center on Sensory and Complex Disabilities at TCNJ. Case 4 involved the same conditions as Case 3 plus a group interview with a recent alumnus who has a vision impairment.

Reflections: After completing the low vision simulation, students were asked to write a reflection of their experience in the course online discussion forum. Participants were asked to post a response to the prompt below and also post two replies to their classmate's posts.

> "Describe your experience today wearing the low vision simulation goggles/ blindfolds. What did you learn about living with a vision impairment? Did this activity help you break any misconceptions that you held in the past?"

The qualitative analysis of their primary reflections is analyzed elsewhere but shows that overwhelmingly students felt a sense of vulnerability during the simulation which could have influenced their chosen design solution.

Design Quality Rubric: Each final project was evaluated by two researchers using a design quality rubric, as described by Sobek and Jain [14]. The assessment rubric was developed to evaluate the outcome quality of engineering design capstone projects. The rubric is designed to be objective so only the prototype quality is assessed. For the present study, the satisfaction of the end user was not considered because there was not a large enough sample size of individuals available for an interview who have a vision impairment.

Since the interventions in this study were implemented in an introductory design class some of the rubric definitions were adapted to assess the three-week design project, including the scale model, prototype and presentation. However, metric categories were consistent with the design quality rubric [14] (Table 3). For the metric of meeting requirements, teams had to produce a scale model of the dorm room and their final prototype had to properly fit in the model. In addition, the prototype and presentation needed to demonstrate that the team completed research on vision impairments and it needed to address a problem associated with the tasks of daily life. It was expected that the final design solutions incorporated ideas of universal design. The metrics for feasibility and simplicity were not changed. To the metric of creativity, the idea of risk taking was added to recognize innovative approaches. The metric of overall included the team's performance during the final presentation, the aesthetic qualities of the scale model and the overall impression of their proposed solution.

Table 3: Metrics and definitions used in the Design Quality Rubric to assess the completed prototypes.

Metric	Definition
Requirements	scale model of dorm room, improves accessibility for blind and vision impaired, considers daily life, universal design, provides additional research and added initiative
Feasibility	practical application, realistic implementation, manufacturability
Creativity	includes innovative implementation approaches, demonstrates risk taking in design
Simplicity	minimal, functional, reliable, practical
Overall	ability to answer presentation questions/ concerns, impression of design, prototype shows potential for development

RESULTS:

The use of the adapted design quality rubric allowed the researchers to quantify the prototype quality that resulted from each course section. Each project was individually scored by two researchers and they were not aware of the relationship between simulation intervention (Case 1 - 4) and class section. The metric scores ranged from 1 through 7 with 1 signifying a poor effort, 4 demonstrating an acceptable effort, and 7 depicting an outstanding effort. Each metric was averaged and graphed by section number (Figure 1). After two rounds of discussions about the metric definitions the inter-rater reliability was calculated to be 82% [15].

The simulation intervention for case 1 only involved the blindfolds and they received similar scores in the metrics for creativity, and overall. This class section scored the highest in the metrics for simplicity, and overall when compared to all the other class sections. In general, their projects focused on using various textures to create functional, easy to recognize zones or pathways in the dorm rooms.

The simulation intervention for case 2 involved the simulators and blindfolds. In general, teams in this class met the requirements and had a positive overall score. The final prototypes were evaluated with the lowest scores in the metrics of feasibility and creativity when compared to all the other class sections. This class averaged a 6.0 on the metric of simplicity which means their prototypes were practical and functional for the problem statement. This was the highest score for this metric among all class sections. In general, their final products focused on the daily lives of students within the confines of a dorm room.

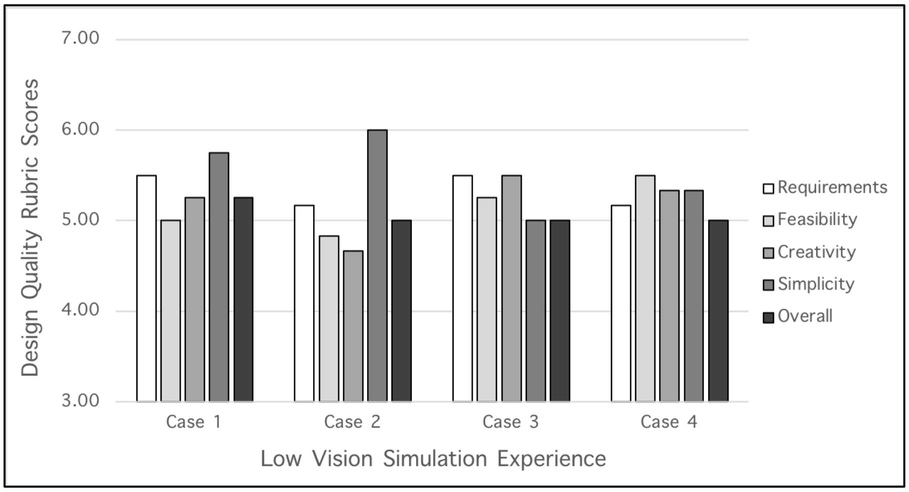

Figure 1: Design quality rubric average scores in the four class sections for the five metrics; requirements, feasibility, creativity, simplicity and overall.

The simulation intervention for Case 3 involved simulators, blindfolds, and a training session. This class scored highest in creativity but lowest in simplicity when compared to all the other class sections. In general, the design prototypes for this class focused on assistance, utility, and consideration for others.

Case 4 had the most complete simulation intervention as the students experienced using the simulators, blindfolds, attended a training session, and as a class interviewed a student with a vision impairment. This class scored highest in feasibility when compared to all the other class sections. The other four categories received positive scores. In general, the design solutions for this class focused on safe navigation and indirect assistance modifications.

Figure 2 shows representative photographs of the final design prototypes displayed inside the dorm scale models for each course section. The photographs in squares A, B, C, and D correspond to class simulations case 1, case 2, case 3, and case 4, respectively. Figure 2A shows how one team focused on the importance of varying the floor textures to create functional zones in the room. This potentially makes it easier for someone to find a part of the room and associate it with a specific function. Figure 2B shows how one team developed the profile of a company named “St(eye)les” that developed a variety of products to address the needs of people who have a vision impairment. They gathered inspiration from their challenging experience of using the microwave while wearing the low vision simulators. The appliances are designed to have large faced buttons in contrasting colors to make them easier to find and provide a voice feedback when activated. Figure 2C shows a team’s design of a portable light that could be moved around a room to remove dark spots but at the same time not be overbearing in disrupting roommates or visitors. Their focus was to overcome the challenging nature of completing daily tasks without adequate and evenly distributed lighting. Figure 2D shows an approach to safely locate furniture in the room. The team developed specific pathways made from textured floor tiles to navigate around the room.

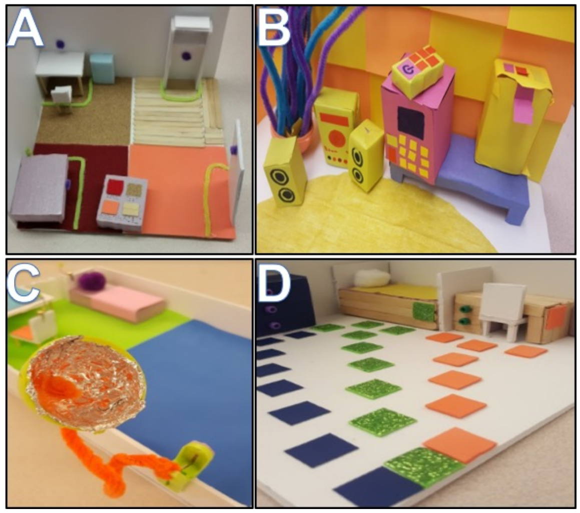

Figure 2: Photographs of representative final scale models with the prototype displayed in each room. A) textured flooring for functional zones, B) electronic feedback buttons on appliances with contrast and large labeling, C) portable sun lighting system and D) textured pathway tiles. (A, B, C, and D correspond to class simulations case 1, case 2, case 3, and case 4, respectively).

DISCUSSION:

The results of the present study were contrary to the initial expectations as the experiential simulation and training did not seem to have a correlation with the quality of the final prototypes as measured with the design quality rubric. First, it was expected that students who underwent the experiential simulation with blindfolds exclusively (Case 1) would have developed prototypes related to problems with navigation and disorientation because of a limited understanding of blindness and the various vision impairments. Instead some of the highest scored prototypes came from this group. In this class section, at least two teams went beyond what was suggested and took it upon themselves to interview students on campus who have vision impairments. Their initiative should be celebrated but unfortunately it skewed some results of the baseline group. Perhaps, this occurred because design thinking is a core topic in the course and it encouraged students to seek out additional information. It is also probable that students from different course sections communicated with each other about what was occurring in their class and it influenced them to follow similar approaches.

Second, it was also expected that the complete experiential simulation with simulation goggles, blindfolds, training session and a group interview with a person who had a vision impairment (Case 4) would help teams better understand blindness and lead teams to generate creative and high quality prototypes that met all the requirements. Instead, the designs were very similar to each other and on the design quality rubric they scored lower in the metric for creativity than in other sections. It is possible the training session and the class interview steered teams to only consider a few themes. Meeting a person with a vision impairment could have also influenced students to consider the interviewee to be the expert and therefore the teams thought best to design a solution to meet the specific needs of that individual.

It was observed that most teams were fixated on the idea of developing prototypes or modifications that would improve navigation in a dormitory regardless of the simulation intervention provided. Many of the practical ideas included textured floors, lighted areas, room guard bars, etc. Perhaps this was due to the impact of the low vision simulation with the blindfolds. The immediate feeling of not being sighted through the experiential simulation caused students to feel vulnerable in finding their way around in an unfamiliar environment. This has been discussed by Silverman et al, who found that an experiential simulation of blindness can temporarily give a volunteer the feeling of being blind, but then causes them to self-reflect and feel less capable of facing challenges [11].

Although a positive correlation between the degree of experiential simulation and final design quality was not established it is interesting to note that groups did meet their design requirements. Out of all 20 teams only one team scored below a score of 4 in multiple categories of the design quality rubric, meaning they did not develop an acceptable solution. This suggests teams in general were engaged in the design activity because of the simulation and the connection to a social problem. Throughout the design process they remained motivated enough to develop final designs of high quality. This agrees with previous studies that show how human centered design can be an effective strategy to aid in the learning progressions of students [16]. Although, this was not implemented in this version of the design study, it would be interesting to run the design activity in a class without any kind of low vision simulation and then compare the quality of their products to the other class sections.

Many groups also carried out their initial design idea to the end. This is a classic example of beginner designers rushing into an idea without considering alternatives [2]. This occurred in spite of the design process followed in class where each student had to brainstorm multiple ideas and then perform an evaluation matrix to assist in choosing the best decision. It seems most teams did not look deeper into understanding how students with vision impairments would naturally adapt to navigation in small spaces.

CONCLUSION:

An experiential simulation on vision impairments was used to teach engineering students as well as students from other majors about the engineering design process in an introductory level creative design course. There were many benefits in accomplishing the task of designing a product for a dorm room that would improve accessibility for students with vision impairments. From written reflections, it was clear that the experience of the low vision simulation motivated students to complete their design projects. We also observed that the degree of low vision simulation gave students a different perspective into the problem. However, careful administration of the experiential simulation is important because it can reinforce misconceptions about disabilities and cause teams to fixate on self-observations from their experience rather than thinking of the actual user. If available, a trained professional will make the simulation most effective and possibly reduce the feeling of vulnerability.

The complexity of the simulation did not seem to affect the quality of the final projects as evaluated with the design quality rubric. The average scores for the five metrics: requirements, feasibility, creativity, simplicity and overall did fluctuate by class section but there was no correlation to the simulation type. Even in the case where students were only given blindfolds, teams still exceeded the expectations and went out to interview current students with low vision. Whenever possible, it is recommended that multiple users be available for interviews that way teams can hear from a diverse group of people. In this study, one user became the expert in that course section and teams overwhelmingly developed designs specifically for that person. It would be interesting to repeat the study but allow teams to meet users in a comfortable environment away from the classroom that way students can observe daily actions while asking questions at the same time.

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