

Teaching Students Designer Empathy in Senior Capstone Design

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This paper will discuss the importance of incorporating user empathy in the design of biomedical products while also addressing the challenges involved during the absence of empathy in the design process. Understanding the end user's needs is a critical component of design. This process is made increasingly more difficult when the designer is not able to fully understand the needs of the product stakeholder or the requirements of the product. A biomedical engineering senior capstone design project that took place at Florida Institute of Technology, where a team of engineering students were tasked with designing an all-in-one wheelchair that provides multiple positions, allowing the user to sit, stand, and recline, will be presented to further support this claim. To overcome the challenges associated when there is a lack of empathy, the students employed various methods to incorporate stakeholders within the design process. These methods will be described and recommendations will be provided for educators to formally address this within senior capstone design classrooms. Healthcare related engineering presents a unique challenge that is not realized in other engineering disciplines and must be addressed accordingly. Educating students on this aspect of the design process is of particular importance, as most engineers employed within the biomedical field will develop systems that make their way to disabled or ailing individuals.

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Empathy Challenges in Satisfying Requirements

The most effective measurement of success for any engineered product is satisfaction of the needs of its users. For engineered products to be successful, they must accurately fulfill the requirements of the product's stakeholders¹. Performing a thorough requirements elicitation to fully develop and truly understand the needs of the end user is recognized as a critical component of the design process^{2,3}. However, this process is made significantly more difficult when pertaining to end users with which the designer is not familiar^{2,3}. Design issues can be further exacerbated when the designer is not familiar with the specialized products created.

Educators address the familiarity gap by introducing various requirements elicitation techniques to students. Students are informed that stakeholders, such as consumers, have a perspective based on their experiences that can shape their needs for a product^{4,5}. When a designer lacks empathy for the needs of the end user there is a greater challenge throughout the entire design process^{2,3}. For instance, collecting data from users during prototyping to collecting design feedback is an excellent approach for a designer to fully understand the requirements of the product.

A prominent example of this is the design and development of biomedical products. Most engineers don't possess the same latent needs their end users possess^{2,3}. An example of this is demonstrated in this paper where a team of engineering students, comprised of biomedical and mechanical engineering majors was

tasked with designing a wheelchair capable of multiple positions, including elevating the user to the standing position. Students were able to overcome some of the challenges associated with designing for a user they lack empathy for by utilizing practices that place the end user at the epicenter of their design. Educating students on such practices is of particular importance, as most engineers employed within the biomedical field will develop systems that make their way to a disabled or ailing individual.

This paper will detail a senior capstone design (SCD) project where a team of engineering students were tasked with designing and building a product for a user they could not empathize with and the challenges encountered during this experience. Methods for mitigating these limitations will be presented to provide educational recommendations. This paper will also investigate the unanticipated, yet beneficial, experiences students gained beyond engineering design through this project. Specifically, the challenges involved in incorporating the physical, physiological, and psychological needs of the end-user, and how students were able to overcome these challenges and deliver a more successful design.

Senior Capstone Design at Florida Institute of Technology

At Florida Institute of Technology SCD spans across three semesters: second semester junior, first semester senior, and second semester senior. The first course, Design Methodologies, serves as an introduction to

formal design methodology and prepares students for their SCD project. Design Methodologies is a one credit-hour course that meets weekly to detail the design process, how to use it, and test cases. The objective of this course is to equip students with the design tools necessary to successfully complete their SCD project. The four key objectives of this course are to enable students to:

- Utilize various design tools, techniques, and methods employed in engineering design;
- Successfully manage and document projects;
- Recognize the role of analysis, synthesis, and evaluation in design; and
- Apply the fundamental concepts of professional and ethical responsibility

During the subsequent two courses, completed during senior year, capstone projects are assigned and completed within student teams. These courses allow students to demonstrate their understanding of the theory in a practical, real world engineering challenge and gain experience. Teams present weekly to an advisory board consisting of at least a customer, professor, and a graduate student. This advisory board serves to monitor student progress throughout the course of the project.

Designer Empathy

Empathy is defined as the experience of understanding another person's intellectual state or condition from their perspective - commonly referred to as "putting yourself in someone else's shoes"³. Studies have shown that individuals can more easily empathize with others they share the most contact or similarities with, such as similar lifestyles and geographical, religious or ethnic backgrounds³. Because the majority of engineers are not disabled, this is of particular importance when it comes to the ability to empathize when designing a product for a disabled or ailing individual. Engineers are often tasked with creating or innovating products geared towards such users with a vast range of limitations.

For engineers to better design and integrate human factors into their products, the ability to empathize with the end user can be an important part of the design process; this is especially true when designing products for disabled and/or dissimilar end users, where physiological and psychological needs of the user must be taken into account throughout the design process^{2,6}. Simply providing engineers with the details of how to solve a given problem for a particular group of disabled individuals is not enough to address all the challenges associated with a lack of designer empathy⁶. A lack of understanding and empathizing for a disabled or ailing user can lead to products that are inefficiently, and sometimes inappropriately, designed^{2,6}. While these products may be "accessible" to such users, they can often end up being unusable in practice^{2,6}.

Engineering students have been shown to have significantly lower empathy when compared across various fields of study³. This is why it is important that engineering students gain skills in empathy, in addition to the theoretical and practical methods most commonly taught throughout engineering education³.

Empathy in Biomedical Engineering

Biomedical Engineering enrollment is growing at a faster rate than most engineering disciplines, thus demanding greater attention in its education⁷. The rise in student enrollment is matched with an increasing population of disabled and elderly individuals in the US, resulting in a rising disabled user base. This is prompted by continuous improvements in health care and prolonged life expectancies⁸. As most of these students will gain employment in a healthcare related field, it is important that they are able to empathize with disabled or ailing end users.

Design Motivation

The wheelchair designed for this project was aimed at patient's suffering from spinal cord injuries (SCI). The design presented can enhance quality of life while also providing a number of health benefits for SCI patients^{9,10}. Patients who have suffered a SCI experience an immediate and drastic change of lifestyle. In the blink of an eye, these patients suffer from motor function loss, paralysis, and often times lose the ability to walk^{11,12}. The devastation associated with SCI extends well beyond the physical body, with patients suffering psychological and emotional trauma as well^{9,11,12}. This was an integral consideration to the project, as the team did not initially consider the emotional trauma associated with SCI when collecting data pertinent to the design. Thus, it is important that students navigate the data collection process cautiously.

When analyzing possible solutions for the design, the team had to consider the psychological aspects of being constantly confined to a wheelchair during all aspects of daily life. Based on the information collected, the team felt it was important to provide patients with the ability to move from the seated position to a fully upright, standing position^{9,10}. By restoring the patient's line of sight to where it was prior to injury, this product has the ability to provide a substantial and beneficial psychological impact for the users, improving their ability to participate in daily activities^{9,10}.

When researching common problems experienced wheelchair users, rotator cuff injuries were found to be prevalent when used over an extended period of time¹³. Wheelchair users must now perform a function with their upper extremities that was previously performed by their legs. After losing functionality in their legs, patients don't want to lose their arm function as well. To combat

this, a lever propulsion mechanism was implemented. This changes the major muscle groups used for propulsion and reduces the stress on the patient's shoulders when compared with standard hand-rim propulsion¹³.

Wheelchair models such as the Karman manual power stand XO-101 and Helium LSA chair, with an estimated retail price of \$6,000 and \$11,000 respectively, provide solutions for some of the aforementioned problems¹⁴. However, their high costs are not feasible for most wheelchair users, nor do they include all of the positions and functions incorporated into the All-in-One wheelchair design. The goal of the project was to satisfy all of the demands met by similar products, combine these solutions into a single design, and do so at a fraction of the cost in order to provide an affordable, readily available solution for SCI patients.

Design Project Experience

Students were tasked with designing an all-in-one wheelchair that provides multiple positions, allowing the user to sit, stand, and recline. The wheelchair is propelled using a lever driving mechanism. When compared to conventional hand-rim propulsion, this type of motion (lever propulsion) decreases the demand on the user's smaller shoulder muscles and redistributes it to larger muscles, such as the anterior deltoid and infraspinatus¹³. The wheelchair also provides pressure relief via a reclining mechanism, leg elevating mechanism, and specialized seat cushions.

Additionally, the design seeks to improve social interactions by elevating the user to a more natural position. Patients can "stand upright" next to friends and family while conversing, as they were able to prior to their injury. The design also seeks to reduce the overall cost to the patient by combining multiple devices into a single, more affordable option. A picture of the final designed wheelchair is shown in Figure 1.



Figure 1: All-in-One Designed Wheelchair

Educational Recommendations

Engineering education rarely provides students with opportunities to go into the field and interact with the various disabled end users and stakeholders that will utilize the products designed. Increasing such opportunities is one way to prepare students and provide them with real-world experience in an effort to promote empathy in engineering design. This can be accomplished by visiting rehabilitation or medical facilities, interviewing and retrieving patient feedback on products they use daily (specifically their likes and dislikes with those products). Similarly, reverse engineering can serve to inform students on why specific products were designed with its functionality and features – helping students to empathize with the need for such functions and features.

When communicating with disabled or ailing individuals it is important to consider the language used¹⁵. Students found that often times, these users expressed difficulty and remorse when discussing or explaining their wheel bound condition. It is important to approach such discussions carefully. When communicating with and about disabled individuals it is recommended to speak in a manner that reflects the patient's individuality, use affirmative phrases/terminology, and avoid group designations, such as "the blind"¹⁵.

Bringing in disabled or ailing guest speakers is another mechanism to increase student awareness of their needs. Regular exposure to disabled users, their limitations, and how this impacts their ability to perform daily tasks, can provide a worthwhile and meaningful learning tool. This provides an opportunity for students to interact with users and address some of the challenges associated with designing such products thus decreasing the potential lack of empathy. Hearing first-hand experiences from end users and how different devices (or lack thereof) hinder or improve their quality of life, could provide students with meaningful and invaluable insight that is not otherwise learned in a classroom or textbook.

We recommendation students gain exposure to potential stakeholders early and often in the design process, particularly in healthcare related fields. Healthcare related engineering presents a unique challenge that is not realized in other engineering disciplines and must be addressed accordingly.

Results and Analysis

Interacting with, and involving stakeholders early on when designing biomedical products is imperative^{2,6}. Keeping them involved throughout the entire design process is one way for engineers to overcome their lack of empathy for disabled or ailing individuals. Getting stakeholder feedback on various design components and iterations, beyond the initial design, can play a critical role in the effectiveness of a product's design and

functionality. It is important to note that students often do not recognize the empathy gap that exists. While it is important to teach students various empathy related techniques, tools, and methods, it is equally important that students recognize when a lack of empathy does exist.

The observations of SCD indicated students struggled to develop requirements and collect customer feedback when the end user was not intimately involved in the design process. To address this, students met with end users from a local rehabilitation center who used wheelchairs in their daily life. Users provided students with details on their day to day routines, explaining how they use their wheelchair and what its limitations are. Anecdotally, the teams improved when acquiring data from their end user whom they lacked empathy for. While this helped substantially, some challenges persisted. For example, students made it a priority to visit their end user when questions existed. However, there occurred a gap in their metacognition of what questions to ask because they didn't realize what questions would be important. As the semester progressed, students visited the end users even when they didn't have questions and kept it as an open forum for feedback.

In addition to the end user, students met with an orthopedic surgeon who explained the medical complications associated with long term wheelchair use and how this can cause complications in the shoulders of its users. Students met with such stakeholders often and used this information in their design iterations. Some meetings were used to collect information while others were used to test prototypes.

Conclusions

This paper detailed the importance of designer empathy and the role it plays in SCD. There are several methods that can help to bridge this gap, and in health-related fields, it is imperative engineering students are educated on this. In the SCD project presented here, where a team of engineering students were tasked with designing and building a wheelchair, the students demonstrated an ability to connect with the stakeholder through multiple meetings, prototype reviews, and meetings with medical personnel. This assisted the team in both requirements elicitation and prototype feedback.

The success of projects where the end user is a disabled individual is highly sensitive to the requirements elicitation process^{2,3}. While a new requirements development process is not promoted here, the authors do recommend that special attention be given to this process, as it will necessitate greater resources and time to accurately enumerate the needs of the end user. For example, additional focus groups and iterations may be necessary before acquiring accurate requirements.

It was observed that students struggled to iterate on their prototypes when the end user was not involved. Thus, it is imperative end users be involved from the early stages of the design process for engineers to gain a proper understanding of the constraints bounding the design and scope of the project.

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