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Student Perceptions of Design Projects That Involve Developing Assistive Devices for Elementary School Children with Disabilities

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Abstract

One of the major goals of the engineering profession is to improve the human condition. It is therefore important for engineering educators to introduce the idea of public service so that students can recognize the potential impact their profession can have on society. One unique approach to engaging engineering students in service-based learning involves the design and development of assistive devices for persons with disabilities. Some previous papers specifically discuss incorporating design projects involving assistive devices into capstone design courses, but no literature exists that provides a clear understanding of how engineering undergraduate students participating in such projects perceive the opportunity as a means to learn engineering skills. This project begins to fill this major gap in the literature.

Teams of undergraduate mechanical engineering students at Loyola Marymount University were tasked to develop assistive devices during their yearlong 2012-2013 capstone design course sequence. For these projects, the student teams partnered with WISH Charter, a nationally recognized local free independent charter elementary school that is dedicated to providing an inclusive educational environment for all children. In a full inclusion setting, students with disabilities are educated alongside students without disabilities as the first and desired option while maintaining appropriate support and services. A growing body of research indicates that inclusive education is an effective practice for most students. For example, it is well documented that inclusive education can yield positive outcomes for all of those involved, including the focus students, typical peers, classroom teachers, and the school community at large.

The engineering student teams were required to submit their designs to the 2013 RESNA Student Design Competition, an annual competition sponsored by Rehabilitation Engineering and Assistive Technology Society of North America. This paper will provide a discussion of the design projects and a qualitative assessment of how engineering undergraduate students participating in such projects perceive the opportunity as a means to learn engineering skills. In particular, this paper will utilize an open-coding approach to identify emergent categories in post-intervention student responses to questions regarding student learning and development as professionals and as members of society in general.

Introduction

The inherent civic responsibility that comes along with being an engineer has led many engineering educators to expose students to engineering-specific service experiences. Service-based learning is a pedagogy in which students engage in activities that address societal needs while simultaneously addressing learning outcomes. Experiences can involve course-based service learning, as well as both co-curricular and extracurricular service experiences. According to the National Service-Learning Clearinghouse, "service-learning is a teaching and learning strategy that integrates meaningful community service with instruction and reflection to enrich the learning experience, teach civic responsibility, and strengthen communities."[1] Although service-learning programs are quite diverse in their approach, there are certain common characteristics among them. According to Eyler and Giles, service-learning experiences:

- Have a positive effect on student personal development,
- Involve cooperative experiences and promote leadership, teamwork, citizenship, and communication skills in participating students,
- Address complex problems in complex settings, offering participants the opportunity to develop mature problem solving skills, and
- Are likely to be personally meaningful to participants and enhance their social, emotional, and cognitive learning and development.[2,3]

Service-based learning in the engineering disciplines essentially utilizes service as a vehicle for both professional and technical knowledge gains. The use of service in engineering education in the United States began in the 1990's (e.g., see Tsang et al.[4] and Duffy[5]) and has recently increased based on the need to reconsider the priorities of the professoriate,[6] a desire to improve human conditions to fulfill higher education goals,[7] and to meet the interest and demand of students and faculty across the nation. Some examples of exemplary engineering service-learning programs include: The Engineering Projects in Community Service (EPICS) program developed in 1995 at Purdue University,[8] The Service Learning Integrated throughout a College of Engineering (SLICE) program at the University of Massachusetts Lowell[9], and both the Engineers Without Borders (EWB)[10] and the Engineers for a Sustainable World (ESW).[11]

One approach to engaging engineering students in service-based learning involves the design and development of assistive devices. In particular, this paper will focus on the development of assistive devices for local elementary school children with disabilities in an effort to promote inclusive education. Prior to 1975, many states actually had laws that explicitly excluded children with certain types of disabilities from attending public school[12] and as a result, U.S. public schools only accommodated one out of five children with disabilities.[13] At the time, more than 1 million children in the U.S. had no access to the public school system.[12] Many of these children lived at state institutions where they received limited or no educational or rehabilitation services.[14] Another 3.5 million children attended school but were in segregated facilities and received little or no effective instruction.[12] The 1990 U.S. Individuals with Disabilities Education Act (IDEA), most recently amended in 2004, ensures services to children with disabilities throughout the nation and governs how states and public agencies provide early intervention, special education, and related services to more than 6.5 million eligible infants, toddlers, children, and youth with disabilities. The IDEA defines a "child with a disability" as a "child with an intellectual disability, hearing (including deafness), speech or language impairments, visual impairments (including blindness), serious emotional disturbance, orthopedic impairments, autism, traumatic brain injury, other health impairments, or specific learning disabilities; and, who, because of the condition, needs special education and related services."[15] Our projects specifically worked with children with a range of disabilities as categorized by IDEA and who have an Individual Education Plan (IEP). An IEP establishes the individualized objectives of a child with a disability as defined by federal regulations. The IEP is intended to create a specific program for educators to help children reach educational goals more easily than they otherwise would.[16]

In a full inclusion setting, students with disabilities are educated alongside students without disabilities as the first and desired option while maintaining appropriate support and services. A growing body of research indicates that inclusive education is an effective practice for most students. For example, it is well documented that inclusive education can yield positive outcomes for all of those involved, including the focus students, typical peers, classroom teachers, and the school community at large.[17-19] Outcomes for students with severe disabilities include increased social participation and access to general education curriculum,[20-23], learning and generalization of new social, sensory, motor, and communication behaviors,[24,25] and improvement of the overall quality of IEP objectives.[26,27] Significant benefits of inclusion have also been reported for class members without disabilities including increased sensitivity, empathy, and appreciation of human differences, as well as increased access to cooperative learning opportunities and assistive technology.[28,29] A recent study identified six positive outcomes of the inclusive model at the elementary school level: acceptance of diversity, student achievement, development of friendships, a positive and supportive environment, professional growth of personnel and the effectiveness of collaborative teaming.[17] As such, school districts across the U.S., including the Los Angeles Unified School District (LAUSD), are actively working to reduce the number of students with moderate to severe disabilities enrolled in special education centers while increasing their participation with their nondisabled peers.[30] This paper will discuss our efforts to focus on developing custom assistive devices for elementary school children with disabilities while facilitating our undergraduate engineering students participation in unique service-based learning opportunities that promote inclusive education while increasing their awareness of the relationship between the engineering profession and public service.

A total of 31 students participated in the yearlong mechanical engineering capstone design course sequence at Loyola Marymount University during the 2012-2013 academic year. Seven teams of students worked on a total of seven different projects. Two of these projects involved developing assistive devices for local elementary school children with disabilities. The students partnered with WISH Charter, a free public independent charter school within the boundaries of the LAUSD that was established in 2010. WISH is conveniently located one mile from the LMU main campus and serves students in Kindergarten though eighth grade (K-8). The mission of WISH is to maximize every child's learning potential within an atmosphere of caring and belonging. The core element of the WISH model is inclusive education, meaning that children of all abilities, including those who are identified as having a disability or as being gifted, learn together. Each class builds a strong, inclusive community in unison. Students with various strengths, needs, and backgrounds learn together, developing important academic, social, and ethical skills and attitudes.

For one of the projects, four mechanical engineering students worked to create a bicycle attachment for Prime Engineering's KidWalk 2 Dynamic Mobility System. The attachment was specifically designed for Jack, a 10-year old fourth grade student at WISH who has Dystonia, a neurological movement disorder that limits his physical movement, motor functions, and speech. The KidWalk system is a standing gait trainer used to assist with the development of gait and ambulation. Rather than developing a standalone bicycle or tricycle system, the goal of this project was to create an attachment device for the KidWalk system in order to provide Jack with the ability to ride a bicycle (Figure 1, left).

Figure 1. (Left) Jack and his custom designed KidWalk bicycle attachment, and (Right) Abbie and her custom designed iPad Dexterity Enhancement Apparatus (iDEA). Undergraduate mechanical engineering students created these assistive devices for their 2012-2013 capstone design course sequence.

For the second project, another team of four students worked with Abbie, a 5-year-old kindergarten student at WISH who, as a result of Cerebral Palsy (CP), struggles with the fine motor control required to use her iPad for communication. The project's goal was to provide Abbie with the fundamental support and control needed to operate an iPad more effectively. The final design, called the iPad Dexterity Enhancement Apparatus (iDEA), is essentially a supportive, spring loaded tracking system that keeps her hand in an optimal operating position while supporting her wrist to prevent hand dragging. It allows her to use her natural tapping motion, but with enhanced control and guided dexterity (Figure 1, right). Both teams were required to submit their designs to the 2013 RESNA Student Design Competition. Of the 28 teams that submitted their designs to the 2013 RESNA Student Design Competition, this LMU team was invited to attend as one of the six semifinalists and placed third nationally for their iDEA product.

Research Methods

This study consists of a one-phase analysis regarding students' conceptions of working on yearlong senior capstone mechanical engineering projects involving the development of assistive devices for local elementary school children with disabilities in an effort to promote inclusive education. Students were asked at the end of the yearlong capstone course sequence to reflect on and respond to four open-ended questions regarding their perceptions of working on such projects:

1. *How did your senior project impact your development as a professional?*
2. *How did it impact your development as a member of society?*
3. *What did you learn from your project in regards to human needs, especially for those with disabilities?*
4. *How did this project affect your future career plans?*

A total of eight students participated in the capstone projects involving the development of the assistive devices for the elementary school children. All eight students were surveyed and responses were obtained from six (N=6), representing a response rate of 75%.

The questions were designed to identify general conceptions of student learning and development as professionals and as members of society in general. An open-coding approach was taken to identify emergent categories in the data[31-32]. A single rater first read each student's response to determine a set of categories compiled into a rubric. The rubric was then used to code each student's response. A second rater then used the rubric to test its reliability across raters. The second rater repeated a two-step process consisting of 1) coding 10 percent of the responses using the rubric, and 2) consulting the first rater's codes, until agreement was reached. Changes to the rubric were made to establish a high inter-rater reliability between the two raters.

Results and Discussion

Our findings include a post analysis of our experimental group, which consisted of students who participated in yearlong senior capstone mechanical engineering projects involving the development of assistive devices for local elementary school children with disabilities. An overall inter-rater reliability greater than 90% was obtained between the two raters. The authors would like to point out that data from only 6 students was collected and analyzed. Although we present an analysis of our results, we hesitate to infer strong conclusions and generalizations that represent a larger student population.

Four learning area codes emerged from the data for Question 1: "How did your senior project impact your development as a professional?" (Table I). *Provided Design Training* included statements regarding the product development and design process, including making design changes. *Improved Communication Skills* included references to the design reviews and presentations that students participated in, in addition to improving students' listening skills. *Provided a Preview of Industry* represent skills and concepts that students thought would be relevant in industry, including networking, working under deadlines and within budgets, and design prototyping. The final code, *Improved Teamwork Skills,* represents working with other team members and non-technical people, including the client. The majority of students indicated that the projects both provided a preview of industry and helped them develop teamwork skills. In addition, a significant number of students indicated that the project helped them to develop communication skills. Only a small portion of the students indicated that the project specifically provided design training.

Table I. Question 1 emergent categories and example student responses.

How did your senior project impact your development as a professional?	
Emergent Category	**Example Student Responses**
Provided Design Training	*"The project trained me in the methods of traditional product design."* *"The prototyping aspect of the project was key to my growth as a professional mechanical engineer."*
Improved Communication Skills	*"The project greatly improved my listening skills and, above all, my patience. The more intentional time I spent with the client, the more successful the design became."*
Provided a Preview of Industry	*"From this (project), I have a good idea on what is involved when working on a design project for an industrial company."* *"(I) was fortunate to meet with other professionals who design devices for individuals with disabilities."*
Improved Teamwork Skills	*"I feel that my senior project improved my ability of working with others, (including those) who do not have a technical background."*

Two learning area codes emerged from the data for Question 2: "How did your project impact your development as a member of society?" (Table II). *Empowered to Address Societal Challenges* included statements that the students were reassured of their capabilities and were able to look at situations and see how to improve them. The final code, *Increased Empathy* included references that the students' eyes were opened, that they were more aware of persons with disabilities, and more aware of the unique challenges and needs that people with disabilities and their families encounter. The majority of students indicated that their project specifically increased their empathy, especially toward persons with disabilities. In addition, a small portion of students felt more empowered to address societal challenges as a result of working on the projects involving the development of assistive devices.

Table II. Question 2 emergent categories and example student responses.

How did your project impact your development as a member of society?	
Emergent Category	**Example Student Responses**
Empowered to Address Societal Challenges	*"I am more reassured of my capabilities in making an impact on society."* *"(Working on this project) made me better at looking at situations and seeing what could be done to improve them."* *"It was a ton of fun working with a child who was so emotional about the project. Watching how excited he was when he was using (the device) really made us want to work harder and make the design better for him."*
Increased Empathy	*"I felt that my senior project made me much more aware of people with disabilities and the simple things that we take for granted that they must overcome everyday."* *"(This project) opened my eyes to the hardships that many families (of persons with disabilities) go through on a daily basis, (including) rehabilitation which is very expensive and is something I never even had thought about."* *"I learned to take a step back and look at it through the clients eyes."*

Three learning area codes emerged from the data for Question 3: "What did you learn from your project in regards to human needs, especially for those with disabilities?" (Table III). *Human*

Needs are Challenging included statements that the needs of persons with disabilities are easily and often overlooked, support is expensive, and communication and meeting their personal preferences can be challenging. *Diverse Range of Needs* included references to the variety of disabilities that exist, the different levels people have of the same disability, and the unique needs of persons with disabilities. The final code, *Assistive Technologies are Beneficial* represent statements about assistive devices, adjusting such devices to the unique needs of the client, and building such devices to help others. The majority of students recognized that human needs, especially those of people with disabilities, are challenging, especially for those not familiar with such needs. In addition, the majority of students also felt that assistive technologies are beneficial in meeting the needs of persons with disabilities. Finally, a majority of students also recognized that there is a diverse range of needs for persons with disabilities. As an example, the students recognized that people with the same category of a disability might experience different variations and degrees of the disability.

Table III. Question 3 emergent categories and example student responses.

Question 3: "What did you learn from your project in regards to human needs, especially for those with disabilities?"	
Emergent Category	**Example Student Responses**
Human Needs are Challenging	*"I learned that (people with disabilities) are very aware of what is going on, they sometimes just have trouble communicating it with others."* *"It took a while to step back and realize (the client's) limitations and strengths."* *"The basic human needs that many of us take for granted such as washing your hands, walking to go grab a book or even writing with a pencil are very challenging tasks for persons with disabilities."*
Diverse Range of Needs	*"It made me realize that everyone has different needs in society. This project helped us balance those needs."* *"I learned that every individual with Cerebral Palsy experiences a different level of severity of the disability."*
Assistive Technologies are Beneficial	*"There is a huge need for cheaper alternative assistive devices."* *"What I enjoyed most about working on (this project) was being able to work with a client and make adjustments according to (their) needs."*

Finally, four learning area codes emerged from the data for Question 4: "How did this project affect your future career plans?" (Table IV). *Interested in a Related Career* included statements that indicate an interest from the student in pursuing a biomedical career or a career involving assistive technologies. *Currently Pursuing a Related Career* included references that the students will begin working in a related field, such as biomedical engineering, and/or will attend graduate school in a related field. *Desire to Help Others* represents a stated interest to improving their community and help people. The final code, *Significantly Impactful* included statements that working on the project provided a significant impact on the student or was their favorite college experience. The majority of students indicated that they now have an interest in pursuing a career related to the development of assistive devices, such as biomedical engineering. A small portion of students indicated that they were currently pursuing a related career, either through graduate studies or employment in industry. All of the students indicated that this project caused them to have a desire to help others. However, it is unclear whether this experience actually caused this desire or just enhanced or refocused an existing latent desire. Finally, most of the student students indicated that this project was significantly impact on their lives.

Table IV. Question 4 emergent categories and example student responses.

Question 4: "How did this project affect your future career plans?"	
Emergent Category	**Example Student Responses**
Interested in a Related Career	*"This project increased my interest in the biomedical industry."* *"I hope to start my own company that specializes in providing innovative, affordable assistive technology for those with disabilities."*
Currently Pursuing a Related Career	*"I am now pursuing a Master's in Translational Medicine (MTM) degree at UC Berkeley and UCSF."*
Desire to Help Others	*"(This project) made me consider looking for an engineering job that has a primary goal of helping others."*
Significantly Impactful	*"The project greatly impacted my career plans. I'd been searching for an outlet to apply my engineering education towards the betterment of my community."* *"The senior design project was one of the biggest (factors) in my future career."* *"This project was my favorite thing I have worked on in college."* *"This was an overall great experience and helping Jack was extremely gratifying. I would much rather do this project than the other engineering design projects."*

Conclusions

This paper focuses on the student perceptions from participating in yearlong senior capstone mechanical engineering projects involving the development of assistive devices for local elementary school children with disabilities in an effort to promote inclusive education. Our findings include a post analysis of the experimental group who were asked at the end of the yearlong capstone course sequence to reflect on and respond to four open-ended questions regarding their perceptions of working on such projects. Again, the authors would like to point out that data from only 6 students was collected and analyzed. Although we present an analysis of our student responses, we hesitate to infer strong conclusions and generalizations that represent a larger student population. The key finding from our analysis include the following:

- Students indicated that the project both provided a preview of industry and helped them develop teamwork skills. Students also indicated that the project helped them to develop communication skills.
- Most students stated that their project specifically increased their empathy toward persons with disabilities. They recognized that human needs, especially those of people with disabilities, are challenging and felt that assistive technologies are beneficial in meeting such needs. Students further recognized that there is a diverse range of needs for persons with disabilities.
- All of the students indicated that their project caused them to have a desire to help others with their engineering knowledge. However, it is unclear whether this experience actually caused this desire or just enhanced or refocused an existing latent desire. Most students indicated that they now have an interest in pursuing a career related to the development of assistive devices, such as biomedical engineering.

While our work has provided some preliminary useful insights, additional studies are needed to further investigate the perceptions of working on such service based learning projects. Potential future studies include a comparative investigation between students who participated in such projects (experimental group) and those who did not (comparison group). In addition, it would be extremely insightful to survey the users of the devices, along with the students' parents and teachers, to understand what impact these projects had on them. As we continue this research, we aim to shed light on how such service based learning projects impact undergraduate engineering education, particularly the professional development and sense of civic responsibility of our students.

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