International Journal for Service Learning in Engineering
Vol. 9, No. 1, pp. 1-23, Spring 2014
ISSN 1555-9033

Learning Design through the Lens of Service: A Qualitative Study

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***Abstract* – Twenty-four senior-level capstone engineering design projects were completed at a large, public, primarily undergraduate university involving 85 students (70 male and 15 female). All projects involved the design of equipment to facilitate physical activity for people with disabilities. The effects on: i) learning design, ii) attitude towards people with disabilities, iii) motivation to complete team design projects and iv) interdisciplinary collaboration were analyzed through 24 one-hour focus groups. We explored the student experience using a constructivist approach and grounded theory. Four major themes (with associated sub-themes) emerged from our data analysis: learning design (project management, iterative design process, and user-centered design), motivation to complete design (engineering, disabilities, user), perceptions of people with disabilities (previous experience, changed attitudes and beliefs), and multidisciplinary collaboration (etiquette presentation, communication between disciplines, defining roles and expectations). Students completing these projects were shown to appreciate user-centered design, exhibit greater motivation when able to meet and develop a relationship with their client in person, discuss altruistic factors regarding their capstone experience, and were able to develop strong multidisciplinary skills.**

Index Terms – capstone design, design assessment, learning design, user-centered design

INTRODUCTION

People with disabilities constitute a minority group within society and as such are stigmatized in a similar way to other social minority groups.[1] Many people with disabilities can become marginalized through prejudice, stereotyping, and discrimination.[2] For people with disabilities, physical activity provides a range of benefits including physiological, emotional, cognitive, and social aspects[3-4]. The genesis of the work presented in this paper began in 1999 with the creation of an Adapted Paddling Program in the Kinesiology Department at California Polytechnic State University, San Luis Obispo (Cal Poly). The Adapted Paddling Program was offered in collaboration with the Central Coast Assistive Technology Center (CCATC), an organization that provides evaluations, trainings and education to address challenges in employment, lifelong learning and independent living for individuals living in California's Central Coast. Cal Poly's adapted physical activity programs grew the following year with addition of a program called The Friday Club, in collaboration with Special Olympics, and EyeCycle, a tandem cycling program for people or are blind or low vision, offered then in collaboration with the now disbanded Central Coast Low Vision Council.

The cadre of activity programs offered through Kinesiology is now collectively known as Activity4All with the mission of providing and promoting physical activity for people with disabilities. The programs continue to provide practical learning opportunities for kinesiology students while serving the local community of people with disabilities. As the activity programs grew they led to the realization that specialized equipment, designed and built in collaboration with Cal Poly's College of Engineering, might facilitate greater levels of inclusion in physical activity for some of the programs' participants. Initial collaborations with faculty in Mechanical Engineering led to a series of engineering student teams designing and building prototype equipment. The richness of these first experiences led to an increased level of sophistication in both the projects and the multi-disciplinary make up of student teams. The collaboration grew to include students and faculty from Kinesiology, Mechanical Engineering, Computer Engineering and Biomedical Engineering. A series of successful projects attracted attention from far and wide which led to an expansion of community partners to include partners from as far afield as *Bridge to Sports* in North Carolina; *Break the Barriers* in Fresno, California; the US Adapted Ski Team and Disabled Sports Eastern Sierra. Since 2005, this collaboration has led to the custom design of over 100 adapted physical activity (APA) devices for our partners and the people they serve.

In our service-learning program, engineering teams work with kinesiology students as part of an interdisciplinary approach to meeting individual user needs. Engineering faculty advise teams through a design process ending with functioning prototypes. All kinesiology students in the program have previously taken an adapted physical activity class as part of their curriculum and have at least one quarter of experience running and participating in organized adapted sports activities with the local community. These activities include the Adapted Paddling Program (in which students guide sea kayaking daytrips in Morro Bay for people with spinal cord injuries), the Eye Cycle Program (in which students "captain" a tandem bicycle for people with low vision or who are blind) and the Friday Club (in which students help Special Olympics athletes learn a variety of sports skills). The kinesiology students provide expertise in access and abilities for the engineering students throughout the design process. This begins by giving a Disability Etiquette presentation to the engineering students that discusses abelism and appropriate social and professional expectations for interacting with people with disabilities. Later, they assist with testing prototypes with clients.

The different projects designed in our program are identified by our community partners with whom engineering and kinesiology faculty collaborate to outline the project scope and initial design brief given to students. Additionally, as devices age, faculty recruit students to repair and upgrade them as needed for individuals. These devices have the potential to greatly enhance the quality of life for those individuals with disabilities who utilize the equipment. The research presented here evaluates the impact of working on an APA project on engineering students

International Journal for Service Learning in Engineering
Vol. 9, No. 1, pp. 1-23, Spring 2014
ISSN 1555-9033

learning of design, motivation, attitudes towards persons with disabilities and their multidisciplinary collaboration experience.

On Design and Service

A key element of undergraduate engineering education is learning to design.[5] Experience acquired in a senior design course is considered critical for students as they learn how to apply theory while working on a design project.[6-7] Design is an iterative process that consists of devising a system, component, or process to satisfy a desired need. An effective capstone design experience should motivate students to develop a variety of design skills that are difficult to attain in typical lectures and laboratories. Capstone experiences can also provide opportunities for students to further develop program outcomes as specified by ABET Criterion 3a-k. These include the ability to: 1) function on a multidisciplinary team; 2) communicate effectively; 3) design and conduct experiments; 4) analyze and interpret data; and 5) design a system that is within realistic constraints. The number of team-based and multidisciplinary team-based capstone classes across the U.S. has increased[8] since 1995[9], likely due to the influence of ABET on U.S. engineering programs.[8] Faculty in that study report on the capstone as an ideal experience from which to evaluate students' abilities for Criterion 3a-k. Capstone courses require significant faculty involvement, and from the student's point of view, projects should be motivating and challenging but not overwhelming. This requires a faculty advisor to work closely with each student group and external client as project specifications are determined and design concepts are evaluated.[10]

Multidisciplinary capstone design provides students an opportunity to integrate domain knowledge with that from other disciplines in a holistic fashion, considered more relevant in real world contexts than "fractionated knowledge".[11] From a more pragmatic viewpoint, teams in a multidisciplinary capstone experiences have shown superior performance in a variety of design skills and concepts such as innovation, proof of concept and communication skills than their singular discipline counterparts.[12] Yet multidisciplinary design experiences come with challenges that their very form creates. Students may struggle with identifying and valuing the expertise of teammates from other disciplines; they may face uncertainty of each others' roles on the team; and they may face challenges in improving interpersonal skills. [13]

Service learning pedagogy is seen in a variety of engineering and design classes, including multidisciplinary capstone design. Early assessment on the impacts of service learning in engineering focused on retention, diversity, and ABET outcomes including both technical and professional skills.[14] More recent work shows positive effects on modeling and metacognitive strategies in a service-based design context.[15-16] A survey of outcome assessments for project-based service learning show they span knowledge, skills, attitudes and identity with specific outcomes such as cultural competency, ability to communicate effectively, function on multidisciplinary teams, and creative design.[17]

The work of Zoltowski et al. uses a qualitative approach to investigate the manner in which students experience human-centered design when "designing for others".[18] Participants were situated in a variety of learning context including service learning. The authors uncovered seven descriptive categories in their analyses ranging from a technology-dominated view of design to an empathic one. Meaningful connections to clients are likely for students whose views lean toward empathy.

Motivation and Connectedness

Education studies reveal that connections between learning and a broader context have significant positive impacts on individual motivation, engagement, and learning.[19-24] Ford and Smith describe social purpose as an amplifier for motivation and argue that thriving in the context of larger social meaning has positive transformative implications for learning.[25] Coyle et al. underscore the learning opportunities that connections of the technical to broader societal contexts may provide.[26]

Providing students opportunities for social connection through team design experiences and community projects helps to meet a student's basic psychological need of relatedness. Meeting this need, along with autonomy and competence, fosters intrinsic motivation, improved academic performance and healthy psychological growth.[27-28]

Intrinsic motivation is a desirable learning state in which students actively integrate externally motivated (learning) goals and behaviors. Levels of internalization appear on a continuum of different motivational orientations.[29] Whereas intrinsic motivation is a state described inherent satisfaction and goal internalization, amotivation lies at the opposite end of the continuum and is a result of one lacking to identify autonomy, competence, relatedness or value with the learning experience. Between the two extremes lies extrinsic motivation, driven by external factors and rewards. As individuals experience greater autonomy and identify more relevance in a task, they internalize the learning goals and eventually assimilate the learning into their own sense of values and identity.[27] Internalized reasons for achievement-related behaviors positively correlate with measures of empathy, moral judgment, and interpersonal relatedness.[30] These measures, specifically empathy we contend, align well with engineering design experiences in a service-learning context.

PURPOSE

The purpose of this study was to gain greater insight into the effects of completing a team APA design project on: learning engineering design, student motivation and student attitudes toward people with disabilities. An additional goal was to identify student perceived benefits and barriers related to working with an interdisciplinary team comprised of Engineering and Kinesiology students. Researchers were most interested in the salient characteristics of the Engineer-Kinesiology working relationship; one or two Kinesiology students were assigned to provide engineers with background on disabilities facilitate communication with the client and participate in the design process as needed.

This study examines an answer to the broad question, "What impact does completing a service-learning senior engineering capstone project in designing recreational equipment for people with disabilities have on learning design and motivation to complete such a project?" Secondary aims, that are largely programmatic, of the study have the objectives: to evaluate the overall impact and value of the program, to evaluate process and student collaboration between engineering and kinesiology departments, to improve the existing program by adopting student ideas that reinforce the success of the program experience for future students, and to understand if engineering students participating in this project value the experience and confirm the necessity of such a program.

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METHODS

Focus groups are exploratory forms of qualitative research and are considered a useful and credible method to assess and evaluate engineering student learning outcomes.[31] An important purpose of this type of research is to utilize the "needs" and "capacity assessments" the focus group method provides and to engage in brainstorming.[31-32] Its use has a short but rich history in engineering education research and has proven valuable to address questions for which quantitative methods are insufficient.[33-35] The focus group is typically an exploratory process that is used for generating hypotheses, uncovering attitudes and opinions, and acquiring and testing new ideas.[36-38] With recent calls to expand the scope and rigor of engineering education research, use of qualitative methods to answer research questions that cannot be answered through quantitative methods alone or fully has taken on greater significance.[33-35]

A qualitative research framework analyzes data in a constructivist (e.g., naturalistic, hermeneutic, ethnographic, participatory action, symbolic interaction, and phenomenological) fashion from in-depth, semi-structured interviews (focus groups) and written documents (transcripts).[39] It is with this framework that researchers engage in naturalistic inquiry in real-world settings to inductively generate and analyze rich narrative descriptions and construct themes across groups (in our case 24 groups over 5 years). Several authors reporting analyses of qualitative data in journal articles describe this strategy as a "general inductive approach".[40-41] The primary purpose of the inductive approach is to allow research findings to emerge from the frequent, dominant, or significant themes inherent in raw data, without the restraints imposed by structured methodologies. In this type of evaluation research, researchers wish to describe the actual program effects, not just the planned effects. The identification of any significant unplanned or unanticipated effects or side effects arising from course implementation is regarded as an important evaluation task.[42]

Post-project focus groups were conducted with design teams to determine engineering students' perceptions of learning design. Previous experience with people with disabilities and the amount of client interaction were compared qualitatively to examine if those two factors played a role in the project outcome. Narrative evidence of increased technical skill, social responsibility, systems thinking, and communicating as a team effectively, were determined by the team's response to a semi-structured script. According to Lathen et al., it is important to assess if student engineers have "assimilated" the professional roles and responsibilities required to meet the ABET Criterion 3 guidelines.[43]

Focus group questions in this study were designed to: (1) explore if student perceptions (i.e., attitudes, beliefs, and knowledge) of people with disabilities changed as a result of their capstone experience, (2) identify specific design concepts or design processes learned, (3) identify motivating factors for students. (4) identify any academic and project design barriers, and (4) determine if students could identify a natural connection between 'engineering' and 'inclusion'.

Participants

Engineering students were purposefully selected to understand their academic and social experiences from participation in one of twenty-four adapted design projects (n = 85, 70 male and 15 female). All assigned projects had the intent of promoting inclusion for people with disabilities in a specific physical activity. Twenty-four focus groups were conducted from spring 2009 to spring 2013. There were twelve teams of three engineers, eleven teams of four, and one team of five. Projects enabled clients with disabilities to participate in a number of activities, including video games (e.g., Wii), kayaking, bocce, and bowling (See Table I). Criterion sampling was used (i.e., assigned individuals to a given project were selected to attend an approximately one-hour team focus group at the end of their capstone project).

Data Collection & Analysis

The focus group discussion followed a protocol based on a semi-structured interview guide, which was developed in accordance with established guidelines.[44-45] The interview script (see the Appendix), which consisted of a checklist of topics prepared by the moderator, was discussed with the members of the research team and revised according to their comments.

Data were collected at a large, U. S., four-year comprehensive polytechnic public university. Each focus group lasted 50-60 minutes in duration. After each focus group interview, debriefing reports from each session were discussed and recorded by the moderator and two note takers. These reports covered logistics, group dynamics, the moderators' performance, the participants' comprehension, emerging themes and unanticipated findings.[46] The data analysis process for this study was guided by the principles of grounded theory. Constructivism utilizing grounded theory is based on the belief that the world is treated as a product of social interaction which can be observed and described.[47-48] The value of qualitative research to public health professionals and others engaged in multidisciplinary health-related research is recognized and used in this study.[49] Grounded theory is particularly well suited to the analysis of this data in that the goal was to understand the issues that could serve as barriers or assets to the development of an experiential community-based design project.

Table I provides an overview of the composition of each focus group. The project title, year the focus group was run (coinciding with the end of the project; typically at the end of the spring quarter), the number of female and male students from the team present at the focus group, and the number of students who report selecting their project as their top choice. Students were asked about the amount of client contact they had during their project. Their responses were fit to a 5-point scale ranging from low (minimal contact) to high (frequent, weekly or biweekly contact). The aspect of client contact was not explored in the findings of this study.

Coding and Agreement

Focus group transcripts averaged 10 single-spaced pages in length with a range of six to 15 pages. Because of potential confidentiality issues with respondent validation and time demands, this study utilized several methods of data analysis to ensure the rigor of the evaluation research.[50] To ensure reliability, the analysis process involved three coders who read the transcripts and independently wrote a summary of the main issues that emerged for each of the domains. Coders then were instructed to first make notes in the margins defining the main points and identified the main themes for each of the questions. After coders developed these summaries independently, they met to discuss the emerging themes.

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TABLE I
DESIGN PROJECTS, YEAR OF FOCUS GROUP, NUMBERS OF FEMALE AND MALE STUDENTS ON TEAM, NUMBER OF STUDENTS ON TEAM FOR WHICH PROJECT WAS TOP CHOICE, AND AMOUNT OF CONTACT BETWEEN TEAM AND CLIENT.

Project No.	Project Title	Year	# Female Students	# Male Students	First Choice?	Client Contact
1	Hand Foot Powered Cycle	2009	0	4	2	High
2	Universal Play Frame Golf†	2009	2	1	2	Medium-High
3	Foam Wars	2009	0	3	1	Low
4	Wii-B-Fit	2009	1	3	4	Medium-High
5	Strider (youth)	2009	0	3	1	High
6	Sir Ski	2010	0	3	1	Low-Medium
7	APLV*	2010	1	3	2	High
8	Quadricycle	2010	1	3	4	High
9	Foam Wars II*	2010	1	3	3	Medium
10	UPF VI	2010	1	3	0	Medium-High
11	Strider II (adult)	2011	1	3	2	High
12	Untethered Running*	2011	0	5	3	Medium
13	Wii-B-Fit II	2011	0	4	2	Low-Medium
14	Adapted Darts	2011	1	2	3	Medium-High
15	Bocce	2011	0	3	1	Medium
16	Rock-n-Bowl	2011	0	3	1	Low-Medium
17	Pop a Wheelie†*	2011	1	2	1	Medium
18	Adapted Golf Crutch	2013	1	2	3	Low
19	Adaptive Mouth Guard	2013	1	2	3	Low
20	Beach Wheelchair	2013	0	4	3	Low
21	Bocce	2013	1	2	3	Medium
22	Kayak Launcher	2013	1	2	2	Low
23	Knuckle Pucks	2013	1	3	1	Medium-High
24	Untethered Running II*	2013	1	3	4	High
		Total	15	70	52	

Note: The * and † symbols indicate students who reported 'extensive prior experience' to people with disabilities (where * symbolizes one male student and † symbolizes one female student).

Coders then reached consensus on the major themes and sub-themes (Table II). According to previous research, inter-coder agreement must be 0.90 or greater, although 0.70 is considered acceptable for most exploratory studies.[51] When different interpretations arose, coders had extensive discussions until an agreed-upon final interpretation was established. Inter-rater reliability between lead author and two coders were 0.90, 0.93, and 0.92. Once the categories and themes were established, computer supported MAXQDA 10™ (VERBI Software, 2010, Marburg, Germany) qualitative data analysis of the transcripts was conducted. Utilization of both human coding and software coding is useful for triangulation of codebook consistency, dependability, and stability.[52] Software coding also helps to "red flag" or identify responses that were unanticipated (i.e., "other") so researchers can go back and add those responses for inclusion into the codebook if warranted. The researchers identified 17 major codes and 139 sub-codes. The software matches these codes to phrases in the transcripts and reports on the number of hits for each. The researchers then reviewed all matches for verification. The selected quotes presented in the Findings section are representative of the set of quotes for each theme/sub-theme.

FINDINGS

Four themes and nine sub-themes emerged from the focus group analysis. Each theme and sub-theme is described below, along with supporting quotes from engineering students (names have been changed, but not the gender and project of each student). These themes have evolved and expanded from our prior work.[53] Student responses are referenced using the themes identified in Table II.

TABLE II

THEMES, SUB-THEMES AND DESCRIPTORS DERIVED FROM THE 24 FOCUS GROUP TRANSCRIPTS

Major Themes	Sub-Themes	Descriptors and/or Key Terms
1. Learning the Design Process	a) Knowledge and skills b) Attitudes toward client	Assembly; Budgeting; Building; Client; Co-create; Coding; Construction; Creation; End user; Fabrication; Inclusivity; Making design decisions; Management; Manufacture; Meetings; Planning; Scheduling; Stakeholder; Voice
2. Design Motivation	a) Helping others b) Using engineering skills	Analysis; Improving the lives of others; Motivating because an adaptive product; Motivating because of specific person; Process; Seeing a project start to finish
3. People With Disabilities	a) Previous experience and knowledge b) Changed beliefs	Approaches; Changed; Different; Former; Involvement; Knowledge; Mindset; New; Outlook; Preceding; Prior; Reformed
4. Multidisciplinary Collaboration	a) Disability Etiquette b) Communication c) Role expectations	Communication; Custom; Discipline; Email; Expectations; Good Manners; Hope; Meeting; Person; Phone call; Politeness; Protocol; Good Manners; Role; Statement; Task; Text; Workshop;

Inter-rater reliability = 0.90; 0.93; and 0.92

Theme 1 - Learning the Design Process

a. Knowledge and Skills

In design thinking, systematic questioning is integral to effective group project management as engineers generate, evaluate, and realize ideas to achieve client objectives while satisfying a specified set of constraints. However, realistic issues, problems and time constraints were frequently cited as capstone project concerns. Proper delegation of work assignments in terms of

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ISSN 1555-9033

planning, scheduling, and deadlines were discussed by the engineering teams as well as budget concerns. Daniel talks about planning, Ben values his client and not wasting money, and Greg discusses systems thinking and integration.

> Strider II (2011)
> Daniel: *"We had some problems when we started manufacturing in the first couple weeks of the third quarter and we didn't have things quite planned out and I think if we had thought about it more, earlier on, things would have been less stressful, because we weren't able to do anything for the first two weeks of the quarter because we were waiting for materials and stuff and we were still planning things out."*

> Foam Wars (2009)
> Ben: *"It's kind of engraved in our minds for engineering. It's the same in the real world. You can't just create a product and expect the customer to be like 'oh yeah that's awesome.' You have to go step by step to make sure they (client) are with you throughout the whole process so that there are no surprises at the end that cost a bunch of money down the drain."*

> Foam Wars II (2010)
> Greg: *"The whole aspect of fitting… making different subsystems fit together into one system is… you work on one part by yourself, then you need to work with other subsystems do those systems interface. I learned a lot about that."*

The design process involves phases of analytical understanding, critical thinking, and creative decision making; and often times these elements of the design process do not occur linearly. Constant continuous team member interaction is required to complete their design and meet project submission deadlines. The value of most capstone projects is that the projects provide students with an iterative design process with a built-in set of purposive problem-solving procedures over several project phases. Arguably learning design wasn't so much about the end product as it was about the going through the iterative design process as evidenced by the following quotes.

> Strider II (2011)
> Daniel: *"It was a lot more involved than normal projects. It's three quarters long and you go through the whole process of getting the user requirements and designing it and analyzing it and making sure it's not going to break, and of course working with the client was just a lot more involved than any other [project] I have done."*

> Strider II (2011)
> Daniel: *""Just the whole process from going to an idea to an actual product was a huge learning experience. It's a lot more work than I… I mean I expect to be a lot of work which is the whole process…you see a product and you think it's not that hard to make and design but it really is."*

b. Attitudes Toward Client

User-centered design is a term used to describe design processes in which a client influences how a design project takes shape. The end-user is not an afterthought, but rather an important participant in the entire design, development, and fabrication process. In previous studies, age, race, gender, education level, socio-economic status, quality of the social contact (e.g., meaningful), length of contact, marital status, place of residence, and knowledge of the ability of the individual can influence attitudes toward people with disabilities [54-56] Studies examining the general populations' perception of people with disabilities revealed that, in general, females and older individuals have more favorable attitudes of people with disabilities than males or younger individuals.[57-58] Furthermore, individuals who have experience and contact with people with disabilities outside of their work/school setting (e.g., a close friend or family member) tend to have the most positive attitudes toward people with disabilities.[59] The capstone experience is the first chance that most students have to think deeply about a specified user, and many of their comments reflect meaningful learning and altruistic patterns of thought by the following comments.

> Sit Ski (2010)
> Bradley: *"We are just trying to solve problems that people have… with people with disabilities it is looking for products to allow them to regain all of their independence. So if engineers can develop something for that, it would be good."*
>
> Rock-N-Bowl (2011)
> Paul: *"It was in the middle of a very critical time in our project in which we were doing a lot of brain storming and we were kind of…defining some user requirements and just coming up with a basic design, and I feel we didn't have a really good sense of our clients real desires or wants until the end of the first quarter, when we actually presented our idea, and at that meeting we got a whole load of new information, this wasn't that long ago, like a month and half ago."*
>
> Wii B Fit (2009)
> Wally: *"Engineers need to be mindful. Does this product that we are designing and building, can people with quadriplegia use it? If not, what steps can we take to make it more inclusive of all people? That falls into socio-economic… How much does this thing cost, as well. There's a whole bunch of things to consider."*

Theme 2 - Design Motivation

a. Helping Others

Many students chose the adapted physical activity projects because they felt they could help improve the lives of people with disabilities. Nearly all of the engineering teams reported a sense of altruistic beliefs that ultimately motivated them to complete their capstone project.

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Pop a Wheelie (2011)
Paige: *"”We design products so the majority of people can use them and better their lifestyle… they just may need more products to do that in their everyday life."*

Knucklepucks (2013)
Daniel: *"”I was drawn to it. It was a mechanical project for one thing, but another thing was that I’ve never done a project like this before…working to improve someone’s quality of life. I would say I was drawn to that."*

Strider (2010)
Henry: *"”Definitely worth our time. If I’m changing an individual’s life it’s all worth it. I would do it all over again."*

Foam Wars (2009)
Alexandra: *“The success of these projects has impacted everyone involved in an extraordinary way, and has expanded the realm of what is possible.”*

Some of the APA projects were for a specific client who interacted with the students, while others were for remote clients or for organizations (e.g., Special Olympics). Students who interacted directly with specific clients frequently reported increased motivation due to this collaborative partnership.

Adapted Golf Crutch (2013)
Ian: *“I think our [senior project] had more of an impact initially because people were doing projects for big companies just to get them some experience in doing stuff, whereas ours is literally going to someone and we are building it for him; so hopefully it will change his life.”*

Untethered Running II (2013)
Thomas: *“Meeting the client gave us the motivation to really want to give back to her and give her something that she hasn’t been able to do. She’s been kind of let down by projects not being completed the past couple of years, so we wanted to do it for her. She was our main motivating factor.”*

Untethered Running II (2013)
Rocky: “*I have to agree with [Thomas]. I’ve never met anybody like her. She’s not afraid of anything. She’s outgoing. And she is not going to let herself be affected by her vision impairment, and she is going to do whatever she wants to do.”*

Beach Wheelchair (2013)
James: *“No one has really thought of a wheelchair for the beach, it’s not only a cool concept, but it’s going to be helping people down the line.”*

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UPF Golf (2009)
David: *"We wanted to make the club like they were controlling the club and aim like they would be doing on an actual course… we spent a lot of time brainstorming how to make that challenging instead of just pushing a button."*

b. Using Engineering Skills

Many students were motivated by the fact that they were applying their engineering skills to a complex system, independent of the type of project or client. According to a majority of students, simply designing, building, and testing a capstone project from scratch enhanced motivation toward completing their project.

Kayak Launcher (2013)
Jena: *"Thinking of how we're going to transfer a person from a wheelchair to a kayak, the process of how we can do it, figuring out and actually working and seeing it come to fruition, that was what really motivated me."*

Beach Wheelchair (2013)
Kevin: *"For me it was a combination of the building and thinking up designs of the first concepts, and just getting all these creative ideas out there. Getting your hands dirty made me really want to keep going on this project."*

Strider II (2011)
Todd: *"Just the whole process from going to an idea to an actual product was a huge learning experience. It's a lot more work… which is the whole process…you see a product and you think it's not that hard to make and design but it really is."*

Quadricycle (2010)
Julian: *"The fact that it was a blank slate from the beginning was a motivation for people even though we all knew that it was going to be incredibly challenging to start building something from scratch.*

Untethered Running II (2013)
Audrey: *"We had a lot of support not only from our professor, but also from the past project people who worked on it last year,… they really wanted to see it done."*

Theme 3 - People with Disabilities

a. Previous Experience and Knowledge

Prior to the project**,** more females 26.6% had 'extensive' experience working with people with disabilities than males 5.71%; Thirty percent of males reported 'limited' experience and 46% of women reported 'limited' experience working with people with disabilities. Overall males made up the vast majority of the participants that had 'no' prior experience with people with disabilities 65.7% as compared to only 3.3% for females. Although it was difficult to determine if students perceptions of people with disabilities differed based on previous experience many teams

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reported being reminded that people with disabilities represent a group of people who have successfully overcome challenges that life brings.

> UFP Golf (2009)
> Emily: *"Well, like I said I worked at the DRC for about 2 years. Prior to that my only real exposure was my uncle, who is actually paraplegic. He was injured in a car accident. So that was my previous experience was being with him and seeing him as a person."*
>
> Untethered Running (2011)
> James: *"Fairly high. Uh, my parents' friends, a couple of them are social workers so they actually have adults living with them that have disabilities and so that, I had very extensive interactions. And I had one friend in high school who could still kick my butt in chess. So I kind of had some experience. I already knew about the person-first language thing and a few of those things so."*
>
> Pop a Wheelie (2011)
> Paige: *"I have a lot of friends or siblings of friends who have autism and also physical disabilities. Basically since I was 18 I had interaction with them."*

b. Changed Beliefs

The majority of the team responses based on interviews centered on "no change of attitude;" this was especially evident in groups that had limited time with their client. However, 'altruistic' comments were frequent by many of the groups, and many of the student comments indicate significant change and growth as a result of their capstone experience. Andre and Brian report on increased awareness of with people with disabilities.

> Hand Foot Cycle (2009)
> Andre: *"I did not have interactions with people with disabilities before, but now I see things differently. I notice doors and wheelchair ramps. Don't know if it's changed other than that."*
>
> UPF VI (2010)
> Brian: *"Yeah, I gained a lot of knowledge also. More specifically in the fact, in regards to you know it's better to say the phrase "athletes with disabilities" instead of "disabled athletes." Correct phrasing in what's regards to a way that's more politically correct – well not politically correct, but what's a more accepted way to phrase things in regard to people with disabilities."*

Some students address their abilities to interact with people with disabilities and how they view people with disabilities as individuals.

> Bocce (2011)
> Ray: *"I was like so worried on pins and needles the whole time…like… I'm going to do something wrong, I'm going to say something wrong,, so it made me kind of nervous at*

International Journal for Service Learning in Engineering
Vol. 9, No. 1, pp. 1-23, Spring 2014
ISSN 1555-9033

the beginning, and now I feel more comfortable, talking to the client and stuff. It just feels more normal now."

Adapted Mouth Guard (2013)
Sebastian: *"Personally, my attitude prior to meeting an individual with quadriplegia was putting them in a group as someone that I wouldn't be able to talk to. I wouldn't think about it at all, but then, when I actually saw them, I was given the light of how that individual is a person with thoughts such as my own."*

Bocce Launcher (2013)
Maggie: *"I'd say now, because of the project, I'd be less intimidated to approach and talk to somebody with a disability, whereas before I might've been a little intimidated that I'd say something wrong. I've definitely learned through this project to be less intimidated by that."*

Additional students reported on the uniqueness of the individual and looking past a person's disability to see their able-ness yet continued to use objectifying language of "they" or "them".

Adapted Mouth Guard (2013)
Rolf: *"The biggest change for me was less pity, more appreciation for what they do. I was impressed with how much they can do on their own."*

Adapted Mouth Guard (2013)
Herman: *"Before the project I didn't know anything about quadriplegia or anything like that…I never really thought about it. After seeing how they are functional people too…they can do things that we can, just in different ways."*

UPF Golf (2009)
Emily: *"It was interesting to see all the different (clients') personalities. It was just fun to interact with them. Seeing how different each one of them is as a person. I think like wow… it's changed the way I view people who are disabled. Every single one of them is so different, in terms of personality and the things they can do. They are really unique."*

Finally, Oscar links his explicitly design experience with a change in attitude toward a people with disabilities. And Maggie now questions the social construction of the word *normal*.

Kayak Launcher (2013)
Oscar: *"Now that I've actually designed something that could help people with a disability…it makes me see how that even if they have disability, they can still do whatever they want."*

Beach Wheelchair (2013)
Maggie: *"I guess my biggest problem [on defining disability] is with use of the word 'normal'… someone with a disability is not different from someone in what some people would call 'normal'.*

Theme 4 - Multidisciplinary Collaboration

Prior to their capstone design experience, students will have worked with a single lab partner in many classes and in a small team for short, well-defined projects. For most engineering students in our study, capstone design is their first significant open-ended design experience. A team-based, end-user oriented capstone project is particularly effective at integrating the range of professional skills such as teamwork, communication, problem-solving and self-management.

a. Disability Etiquette

When asked about the kinesiology student's disability etiquette presentation, all teams agreed it was helpful in terms of their interactions with people with disabilities. However, a few students, like Margie, reported that the etiquette presentation made them feel less comfortable, 'like walking on egg shells' as one student reported.

> Wii-B-Fit (2009)
> Wally: [On importance of workshop and benefit gained]: *"Yeah greatly… I guess it kind of changed our perspective in a way. Up until now I never knew how I should interact with people with disabilities."*
>
> Pop a Wheelie (2011)
> Forrest: *" "They don't focus on their restrictions but on how they can expand what they can do and having our product being a part of that. That was really inspiring."*
>
> Wii-B-Fit (2009)
> Margie: *"I've gotten more comfortable working with our client, but at the same time I am sort of on my toes… especially after the etiquette workshop making sure I don't say anything wrong that I know is wrong."*

b. Communication

Positive outcomes in working between disciplines were noted by several multidisciplinary teams, especially resonating on working and partnering with an end-user. Multidisciplinary communication, or lack thereof, was one of the most recognized challenges across most teams and was in line with findings from Wojahn et al.[13] In addition to communication problems and demands on time, several teams conversely found valuable experience and insight working collaboratively on their capstone project.

> Wii-B-Fit (2009)
> Margie: *"I'd think the communication between disciplines was problematic…but early on in the quarter it would be cool to get more involvement and more help scheduling things."*
>
> UPF Golf (2009)
> Gina: *"They (Kinesiology students) kind of validated our design as we went along and said 'hey, it's going to be good' or 'No, why don't you use this?' Sometimes it's kind of*

> *nice having an outsider's input rather than just engineering the entire time. They (Kinesiology students) definitely had more exposure to the users than we had. They kind of kept reminding us of things we needed to keep in consideration."*

> Bocce (2011)
> Bart: *"''Communication is big, definitely! Without it makes things difficult. There were times where we were lost in communication!"*

c. Role Expectations

Students acknowledge and appreciate the multidisciplinary collaboration between departments because they understand the need for such skills in the real world. However, focus group discussions clearly elucidated the need to establish clearer roles and expectations for Kinesiology students. Nearly all of the teams we spoke to agreed that this component was perhaps the weakest link in the capstone collaboration as evidenced by the following discussions, again in alignment with the findings in Wojahn et al.[13] Julian, David, and Aidro all report unclear knowledge about the abilities and roles of kinesiology students. Wally relates his role on the team to his expectations of "real-life engineering."

> Quadricycle (2010)
> Julian: *"The Kinesiology students can [help], particularly in the design. We didn't realize maybe it seems obvious but we didn't really take advantage of the knowledge our teammates had till the very end."*

> UPF Golf (2009)
> David: *"I think it was unclear from the beginning what the role of the Kinesiology student was. We had to meet with them all the time but what were they actually doing? So maybe a little more background into that; would help the project in regards to the fluidity and everything."*

> Strider (2009)
> Aidro: *"It was the middle section of the project where we weren't sure what their role was and they didn't seem sure of what their role was in the building (process). We didn't see much that they could help us with."*

> Wii-B-Fit (2009)
> Wally: *"I think it's been cool to participate in an interdisciplinary project like this… it gives you a feel for what real-life engineering is like."*

DISCUSSION

Our multi-disciplinary research team has used the analysis of these focus groups to examine student learning, motivation, perceptions of people with disabilities and interdisciplinary collaboration, while additionally trying to improve the capstone design experience. One of our major goals was to determine how participating in APA design projects affected design learning. Many student comments centered on scheduling, budgeting, and planning; topics that are typically present in capstone projects. After noticing several comments regarding the lack of guidance in terms of the budget in earlier focus groups, our team decided to provide more concrete initial budget constraints. The occurrence of budget-related comments reduced in latter focus groups. A second topic in learning design that was common among all projects was recognizing the importance of the entire design process, including background research, conceptualization, system integration, and the iterative nature of product design.

The students working on the APA projects, however, appeared to have a much deeper understanding of the importance of the user in the design process and a greater appreciation for universal design (design for all users). Having a client with needs that may differ substantially from the general population encouraged students to recognize how important client interaction is during the design process. Students were required to consider mobility impairments, impaired vision, and developmental delays when designing their products. A few of the students discussed the need to consider *all* potential users from the beginning of the design process for *all* products.

Many of the engineering students working on APA projects were motivated to develop an idea into a final product and apply engineering skills to a real-world problem. These students also tended to comment on helping people, and specifically helping those with disabilities. Some students developed deep relationships with their end-users, and often discussed how they wanted to develop a good product for that specific individual. This points to a benefit in having a real local person as a client, with whom students can interact.

With respect to interaction with people with disabilities, most students who chose the APA projects had some prior experience with people with disabilities. More females (26.6%) had "extensive" experience working with people with disabilities than males (5.71%). Students tended to self-report their attitudes toward people with disabilities as having not really changed as a result of working on the APA projects. However, many of their quotes demonstrated a profound new appreciation for inclusivity and universal design. Students mentioned noticing wheelchair ramps and door openings, focused on the abilities of their clients rather than their disabilities, and commented on how their clients were simply unique human beings like the rest of us.

Our thematic analysis of student responses aligns with the work of Zoltowski et al.[18] Our theme on Learning Design aligns with the Category 2 (Service), Category 3 (user as Information Source Input to Linear Process) and Category 4 (Keeping the users' Needs in Mind). Representative quotes from our theme on Motivation to Complete Design is more aligned with Category 4, Category 5 (Understanding the Design in Context), and Category 6 (Commitment to Involving Stakeholders to Understand Perspectives). Evidence indicates a more powerful experience as relationships with clients deepens and supports the work of Ryan and Connell on a correlation between intrinsic motivation and empathy.[60]

We were very interested in the teaming between the kinesiology and engineering students. In the early stages of the project (2008-2009) students discussed their frustration as to the roles of the kinesiology students; similarly, the kinesiology students often felt like the engineering students were not involving them in the design process. Evidently, faculty advisors did not provide the students with enough scaffolding on roles and expectations. As a result of early focus group feedback, we made a number of changes in how we run the APA projects. The kinesiology students are now required to be available during the lab sessions of the capstone design teams; in the past the students decided when and how to communicate, which often resulted in sporadic email correspondence. Additionally, the majority of the APA teams are now placed in the same laboratory sections together; previously these teams were dispersed into sections with industry and faculty sponsored projects. By having all of the APA teams in the same section, everyone had a kinesiology student on their team and it was much more natural to involve them in the entire design process. Finally, the kinesiology APA advisor met with the kinesiology students once a week to discuss progress, and to more fully discuss roles and expectations. However, improving the integration of students from different disciplines into a unified team is something we continually reflect and improve upon.

We also aspire to increase the frequency and amount of interaction between students and clients. Any type of design project would benefit from greater client interaction. Since our students are designing custom devices for specific individuals, we believe significant interaction and, more importantly, empathy is critical.

Limitations

Focus groups were held only with students who worked on adapted physical activity projects. We did not conduct focus groups with students working on industry-sponsored or other types of projects. Hence, there is no evidence from which to draw comparisons between APA and non-APA project experiences. However, we did ask students to provide their perceptions of working on an APA project as compared to their peers on non-APA projects. Some students self-reported that they "know" they had more difficult projects than others because of the level of difficulty of their selected project. Other students, such as Daniel, provide a rich comment on the fluidity of his project.

> Knuckle Pucks (2013)
> Daniel: *" "It felt like a much more fluid process [as compared to other projects] whereas other groups were sort of … they would come up with their design, they would show it in the critical design review, then their sponsor would tell them what changes to make and they would make the changes and that's their final product. Ours was in a constant state of evolution based on showing new things to our client and how he reacted to them."*

A second limitation of our study might be viewed as the five-year time span of our study during which we incorporated student feedback to enhance the design experience for future students. Certainly, we witnessed varying responses to some questions over time. For example, students such as David reported fuzziness with respect to budgeting in 2009,

> UPF Golf (2009)
> David: *"My only suggestion is defining a budget at the beginning and letting us know how much money we have exactly to spend. It was kind of vague in the beginning. They (faculty advisors) were saying, 'design it and it will be okay' and half way through that wasn't the number we were expecting.*

After noting these responses and providing clearer expectations on project budgets, students no longer mentioned budgeting concerns after 2010. If your model of qualitative analysis is one of constructivism, induction, and action research, as ours is, then this example is expected and accepted. We also note that representative quotes for many sub-themes, for example Theme 3. People with disabilities; sub-theme b. Changed beliefs, displayed a sense of time-invariance whereby students responded similarly over the duration of this study.

CONCLUSIONS

All of the engineering teams interviewed perceived a successful capstone experience in terms of learning design and valuing a human-centered project for their client. Motivation to successfully move through the design process was also highly evident for each team based on responses given during the semi-structured interview. As evidenced by our outcomes, focus groups were a valuable methodology to gather engineers' perspectives on their capstone projects that extend beyond the boundaries of the technical. Our findings strongly support the notion that engineering students perceive their capstone learning experiences as having had a direct and profound effect on their learning. Based on our findings, we believe that students completing the APA projects tend to appreciate user-centered design, exhibit greater motivation when able to regularly meet in-person with their client, discuss more altruistic factors regarding their capstone experience, and are able to develop strong multidisciplinary skills. Finally, clients played a pivotal role in students' design experiences. Students developed connections with their clients that helped them internalize their motivational goals with respect to their projects. While this internalization can happen with any type of client, we believe the personal and compassionate nature of service learning design projects provide an ideal environment in which this can and does occur.

ACKNOWLEDGMENT

This research was made possible through the National Science Foundation (Grants DUE-1062297 and CBET-0756210). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation. The authors would like to thank students Bridie Jean McCarey and Ian Rojas for their insights into the findings of this study.

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International Journal for Service Learning in Engineering
Vol. 9, No. 1, pp. 1-23, Spring 2014
ISSN 1555-9033

APPENDIX

Focus Group Script

1. Was this project among your first choice of projects to choose from?
   1a. Prompt (a) number 1, (b) 2-3, (c) 4-5 (d) 6-7
2. Why did you put this project among your top choices?
3. What part of the project did you find most motivating?
4. When you think of your project or design experience, how did it compare to other senior projects that you might have heard about?
   4a. Do you feel your project was more/less/same level of difficulty as compared to other projects?
5. How could your design experience have been made better?
6. What did you learn through this project?
7. The World Health Organization's definition of what disability is: a restriction or lack of ability to perform an activity in a manner or within the range considered normal for a human being.
   7a. Just having heard the official definition of disability, what does disability mean to you?
8. How much experience did you have working with people with disabilities before this project?
   8a. How much contact and interaction did you have with your client?
9. Describe your perceptions of people with disabilities prior to your involvement in this project.
10. An attitude is a mindset, feeling, thought, or opinion on something. Has your attitude towards people with disabilities changed? If so, how?
11. A belief is a conviction, attitude, viewpoint, or thinking on something. Have your beliefs towards people with disabilities changed? If so, how?
12. Knowledge is awareness, facts, comprehension, and understanding. Has your knowledge about people with disabilities changed? If so, how?
13. After working on this project, do you feel more comfortable around people with disabilities?
14. If you attended the "Disability Etiquette" presentations given at the beginning of the project, do you feel they helped?
    14a. Should projects like this include such presentations?
15. What is the relationship between engineering and inclusion?
16. Would you consider a career in engineering focused on people with disabilities?
17. Do you have any suggestions to help improve future projects?
18. Thinking about all that was said here today, is there anything anyone would like to add at this point?