ASSISTIVE TECHNOLOGY DESIGN COURSES: THE MUTUALLY BENEFICIAL RELATIONSHIP BETWEEN ENGINEERING EDUCATION AND THE PROVISION OF ORPHAN DEVICES

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BACKGROUND

Developing assistive technology (AT) might be considered, at first glance as an attractive entrepreneurial activity. However, several aspects of AT development are considerably unattractive from a marketing prospective. The need to compromise between quality and cost is known to all design areas, but it is particularly challenging in an industry that needs to effectively target multiple stakeholders (Bamforth & Brookes, 2002). The uncertain nature of insurance coverage and reimbursement policies, which can vary not only between countries but also across public and private insurance plans, can be a significant barrier for small and medium-sized enterprises (Bauer, 2003). In addition, the wide variety of disabilities creates the need for specific ATs that are often complex to design, but are desired by only a limited number of people (Seelman, 2005). This latter barrier is what defines an orphan device or technology. In 1983, The Orphan Drug Act (P.L. 97-414) described orphan products as drugs or devices for rare diseases or conditions. Even though AT tends to be designed according to functional need rather than diagnosis, the concept still applies. Ultimately, orphan ATs can be described as devices that have great functional value for a small group of users, but little economic value for the producer (Congress of the U.S., Office of Technology Assessment, 1984). Many orphan AT devices might not be become commercially available, because the estimated development costs outweigh the expected sales volume.

Project based learning modules focussing on AT design have gained increasing popularity in engineering education due to the advantages they offer. The societal impact of these activities is a powerful catalyst for students' motivation and it can be helpful in engaging with students who are traditionally underrepresented within the engineering field (Ordóñez, Krishnaswamy, Tull, Ding, & Goldberg, 2014). The direct involvement with clients and the need to plan and execute several steps from initial assessment to product delivery can be a challenging, yet rewarding experience for students. A combination of what is effectively both project based learning and service learning enhances creativity, communication, and critical thinking (Prince, 2004).

It would therefore, seem like there is the potential for a mutually beneficial relationship between AT design courses and the provision of orphan devices. Goldberg and Peralman provided a series of guidelines aimed at improving the delivery of AT design modules highlighting important aspects such as the need to establish multidisciplinary teams, provide intermediate deadlines, promote in-person interaction with the client and help students disseminate their designs via open source repositories (Goldberg & Pearlman, 2013). However, AT design modules which include the delivery of the final product are usually rare, long and aimed mostly at graduate students. Due to the challenges of producing a final product, most modules targeting undergraduate will require students to produce a working prototype rather than a final product (Terpenny, Goff, Vernon, & Green, 2006). Other courses might include the development of an actual product. However, these tend to be long capstone modules which can restrict the scope to projects with a strong discipline specific component (May-Newman, Newman, & Miyares, 2007).

In this paper, we present results and reflections from a five-week summer module developed in collaboration between the Georgia Institute of Technology (GT) and the University of North Georgia (UNG). The course, called Rehabilitation and Assistive Technology Design, provides an inter-professional learning experience for physiotherapy (PT) and engineering students as they collaborate to design ATs for local families. We believe that shorter AT modules based on a Design-Build-Deliver structure are accessible to students from any engineering discipline and can provide an important service to a portion of the disable community that is normally overlooked by traditional market routes.

METHODS

Course Outline

The course syllabus was developed with the structure highlighted in Table 1. The Rehabilitation and Assistive Technology Design module was launched in 2015. Although the general structure of the course has remained unaltered through the years, in this paper we will focus on and provide details related to the year 2016.

Table 1 Course Syllabus

Module's duration:	Five weeks
Number of students:	12 Physical therapy doctoral students 9 Undergraduate (3rd year) engineering students
Outline week 1 (Eng students only)	Introduction to assistive technology and rehabilitation engineering Introduction to lab equipment and manufacturing techniques Completion of small design project
Outline week 2 (PT and Eng students)	Team formation and presentation of design vignettes. First meeting with families, assessment of clients' needs Divergent design activity: Generation of ideas. Second meeting with families: Selection of design concept. Finalization of design concept and presentation Testimonies from past years clients.
Outline week 3, 4 and 5 (Eng students only)	Parts selection Product development and building Delivery to clients Preparation of documentation for public availability

Participants were divided in three teams of seven members, each including three engineering and four PT students, and randomly assigned one of the design challenges identified for the course. The three design challenges presented to the students were: a retro-fit cycle motivator providing audio/visual stimuli to children with learning disability to motivate exercise, a system that could facilitate car transfers for a mother with a severely disabled child and a device able to tether a reverse walker to a stroller for a mother who is concerned her son might become separated from her and the daughter when walking in crowded areas.

Course Evaluation

As a means of evaluating the impact of the course, we asked participants to fill a short questionnaire investigating their experience during the design course. We asked students their opinion on the usefulness and relevance of the course, the perceived difference with other modules, most challenging aspects of the course and their experiences interacting with clients and teammates with different skillsets. Questionnaires were completed anonymously and collected by one of the authors who was not in charge of teaching or evaluating students of either university. Responses were examined using content analysis (Weaver, 2006).

RESULTS

Sixteen of the twenty one students who participated in the course completed the feedback survey, nine were PT students and seven engineering students. The module average usefulness was rated 8.8 on a ten point scale while average relevance was 9.35. Scores were equally high for both PT and engineering students.

The main reason for participation was different according to participants' background. PT students were intrigued by the possibility of collaborating with engineering students, while engineering students were initially more motivated by the strong practical component offered by the module.

Participants unanimously agreed that this course was different from others they had previously attended. When asked to specify what distinguished this module from others, engineering students reiterated the importance of "*real hands-on learning*" and the uniqueness of building a product for a real client "*I had to put more work in it because this was a product that we'd be delivering to an actual family*". On the other hand, PT students were split between the novelty of collaborating with engineers and designers and the technology aspect of the module. The possibility to interact with peers was described as a great learning experience and it was felt that each group brought something important to the table. Physiotherapy students felt like they were able to give important inputs to the design process, but they relied on engineering students for the evaluation of their ideas. On the other hand, engineering students felt that the communication with families and the assessment of children's needs was improved by the expertise and interpersonal skills of the physiotherapy students.

The direct interaction with the families made students feel like their contribution could make a difference in someone's life. Direct knowledge of the client also helped them focus more on the user, rather than the technology alone. It also allowed them to understand how their perspective differs from the perspective of their users' "*I had an idea that I thought it was good in theory, but the parents said it would have been too complicated to use so we had to let it go*". Participants reported that communication with parents was useful to better define design requirements and reveal constraints that could otherwise have been overlooked in a more traditional scenario setting. One of the greatest challenges identified by PT students was their lack of expertise on the subject and some participants felt that they could have given a greater contribution if they were better prepared. On the other hand, engineering students encountered more difficulties during the latter stages of the design process. As they discovered throughout the module, achieving functional operation is often not sufficient when designing a product and other aspects of the interactions between user and device need to be considered "*Once we got the technology working we also needed to address questions on the controls, how the parents will change the batteries and other aspects which took a lot of time*".

Lastly we asked students to single out what they thought were the best and worst aspects of the module. Opinions varied across both PT and engineering students. Some participants were impressed by the amount of new skills they were able to acquire in such a short amount of time and their ability to develop a product from initial conception to final delivery. Others enjoyed more the interaction with families and teammates, while others valued more the fact that their work could have an impact on a child's life. In contrast, students were nearly unanimous in their identification of the worse aspects of the course. Engineering students found the workload for the class intense and they complained that the timeframe for completing the design was short. Physiotherapy students were generally disappointed with their inability to contribute to the product development stage.

DISCUSSION

In engineering education, a strong emphasis is often given to the importance of providing students with a realistic learning experience to enhance the development of practical skills. AT design modules are generally renowned for this and from the feedback collected from participants we can see how this course delivered this effectively despite its limited duration. The relevance given to the practical component of the course, from independent assessment of users' needs to product delivery, doesn't only provide a realistic experience, but a real one. Furthermore, projects involving design of AT for children can help educators to introduce the concept of multiple stakeholders in a simplified manner. The child can in fact be considered the end user of the device but the parents represent stakeholders whose needs must be incorporated in the design if we want to create technologies that will be adopted. Finally, the multidisciplinary dimension of the teams helped students develop organization and communication skills alongside promoting peer learning among team members.

However, as previously stated, students were only one of the two beneficiaries of this course. The products delivered by the students to the families went to fill a gap that was left open by conventional ATs available on the market. On the last day of week 2 of the module we invited clients from the previous year to come and tell the students how the technology they received has helped them, or had failed to help them with their specific need. Of course, we hoped to gather some positive testimonies, but we were positively surprised to discover that all the devices created last year were extremely successful and were still used by the clients on a daily basis. Although the users participating in the course are the primary beneficiaries of the devices created, we always encourage users to share their designs on open source communities such as Instructables, Make: and Thingiverse.

In recent years AT design is becoming an increasingly popular topic within the makers' community. As is shown by Buehler most of the design ideas available in these virtual communities have been generated by hobbyists with an interest in engineering. In our opinion, provided that users have been appropriately consulted throughout the process, ATs developed during a college module could have a greater chance of success compared to others. The fact that they have been designed by a multidisciplinary team guarantees an awareness to multiple aspects of the disability that might not been immediately evident to makers without medical knowledge. At the same time, these devices are realized by students with little or no experience in electronics or manufacturing and they are developed in reasonably short amounts of time which generally makes them easy to replicate. Finally, the structure of an undergraduate course guarantees that these designs have been developed under supervision and underwent evaluation by expert academic staff (Buehler et al., 2015).

CONCLUSION

AT design courses have the potential to provide a tangible benefit to the disabled community while providing an important learning opportunity for students. Multidisciplinary team-based modules focussing on the delivery of the final products to clients will give students the possibility to experience a realistic working environment and will provide disabled users with technologies that might not otherwise be available due to the low economic value of the product.

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