AC 2011-2292: DESIGNING TECHNOLOGY FOR RESOURCE-CONSTRAINED ENVIRONMENTS: A MULTIDISCIPLINARY CAPSTONE SEQUENCE

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Abstract

In this paper we describe a year-long multidisciplinary capstone experience where students engaged in designing and building technology to address problems faced by populations in local and remote resource-constrained environments. We define resource-constrained environments to refer to a range of conditions, including material issues such as limited electricity as well as societal conditions such as low literate populations. Resource-constrained environments provide unique infrastructure, technical, and social constraints that demand innovative design approaches. The course described in this paper built upon previous, similar classes by bringing together interdisciplinary teams of students primarily from the departments of computer science and engineering and human centered design and engineering, who conducted fieldwork with potential user populations to identify a pressing problem, designed a technology to solve that community-based problem, implemented a solution, and evaluated that solution. Students worked on projects with real-world impact and gained valuable experience with multidisciplinary design and multidisciplinary team work. Both sides gained greater appreciation of the difficulties faced by their peers – that fieldwork and software development are both often unpredictable and challenging. Part of the course goal was to provide students with difficult enough collaborations that they would be introduced to the complexity of the workplace, an element of instruction that is often difficult to achieve. In this paper we describe the class format, sample projects, and course outcomes based on student projects and survey responses. The course sequence is currently being offered for a second time.

Introduction

Research on attracting and retaining students suggests that educators should portray engineering as a field through which one can contribute to the social good. ABET, in turn, asks that we provide our students with "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context."[1] Exposing students to ways that technology is having an impact in low-income regions and the developing world is one mechanism for making engineering relevant and showing its power to impact the world positively. In this paper we describe a year-long multidisciplinary capstone experience where students engaged in designing and building technology to address problems faced by populations in local and remote low resource environments. While our primary goal in offering this class is not tied to ABET guidelines, the overlap is certainly beneficial.

ABET also asks that we provide students with "an ability to function on multidisciplinary teams"[1]. One of the strengths of the approach described in this paper is the deep collaboration required by student teams. Throughout this year-long course, students from different departments enroll for different credit levels, and they have to self-manage within their project teams to appropriately distribute the workload, acknowledge varying disciplinary contributions, manage expectations, and ensure that deadlines are met. In addition, because the projects start with open-ended ideation, engage real world populations, and end with an implementation and evaluation, students are introduced to a range of expertise; in order for projects to be successful, project teams also have to discuss various kinds of skills, acknowledge who among their groups can contribute in which ways, and negotiate the contributions of several team members while establishing an appropriate reward structure within their groups. This deep experience with multidisciplinary teams is unique in the curriculum in our departments.

We have worked for many years to develop innovative educational experiences for our students that engage them with broad experiences that meet ABET criteria and prepare them to contribute to their respective professions. In the following pages we describe our latest attempt at such an experience: a multi-term cross-departmental course where students design and build technologies for resource-constrained environments. We define resource-constrained environments to refer to a range of conditions, including material issues such as limited electricity as well as societal conditions such as low literate populations. Resource-constrained environments provide unique infrastructure, technical, and social constraints that demand innovative design approaches. In this class, student groups implemented a variety of resource-constrained projects that forced them to consider design challenges not encountered in their previous engineering courses; this course sequence also forced students to work in teams that challenged their conception of expertise and relevant skill sets. The strengths of our approach with this class is that it requires students to work on group projects that (1) contribute to the social good (if successful), (2) force them to explore local and global impacts of technology, (3) give them experience working on multidisciplinary teams, and (4) work under unique design constraints.

Related Work

There is a long history of interest in incorporating projects that have a positive impact on society into engineering courses via service learning [2-5]. Benefits of service learning include providing opportunities to build stronger relationships between the university and the community and to attract students to the field through the context of projects that have a positive impact on society. While not all projects in our course went on to be directly deployed in the communities for which they were designed, we still saw students driven by an interest in using their design and implementation skills to enable social benefits.

Others have sought to motivate students by the incorporation of open-source humanitarian projects [6] and assistive technologies [7] into senior capstone design courses or as independent study projects. Colorado School of Mines offers a Humanitarian Engineering minor [8]. Socially relevant projects are seen as a good fit for the altruistic leanings of this generation of students [9], and some studies have found that female students in particular are more likely to select humanitarian engineering capstone projects [10].

Our course is based on previous offerings of a computer science course at our university focused on information and communication technologies for development (ICTD) [11]. ICTD is emerging as an active area of research that showcases the connections between computing and the future of billions of citizens of our planet [12, 13]. Similar projects currently exist in many computer science departments and emphasize the importance of collaboration with fields such as public health, education, agriculture, and business. Examples of projects in this area include flood detection, HIV/AIDS tracking, making crop prices available to farmers, microfinance, transportation coordination, and governance. A few universities are beginning to integrate the topic of ICTD into their undergraduate curricula in a variety of ways [11, 14, 15]. Having students work on ICTD-related projects forces them to consider design challenges not encountered in other computer science courses, such as creating low-cost technology solutions suitable for environments with intermittent power and low Internet connectivity, and designing interfaces appropriate for users who are illiterate or have a lack of comfort with technology.

Our course expands on the previous course offering by engaging students from *multiple disciplines* in the design of technology for resource-constrained environments. We define resource-constrained environments more generally than ICTD, encompassing geographic areas in both the developed and the developing world. Expanding our scope allows us to more easily connect students with accessible user populations and clients – essential for our courses' multidisciplinary focus on fieldwork and evaluation of developed technology. Much work has been done on multidisciplinary engineering projects in undergraduate education [16-20]. Our work differs in that it focuses on collaborations composed of students from two disciplines – human centered design and engineering (HCDE) and computer science and engineering (CSE) – one focused on understanding and designing around the human aspect of the problem, the other focused on the technical implementation of those human-centered designs. However, we also build on the motivation and success of the work mentioned above in that the course focuses on projects that have the potential to impact society in a positive way—in our case, in the context of resource-constrained environments, and that it requires students to approach these projects in multidisciplinary teams.

Description of Course Sequence

During the 2009-2010 academic year, we offered a variable-credit, three-quarter multidisciplinary course sequence coordinated between the computer science and engineering (CSE) and the human centered design and engineering (HCDE) departments at the University of Washington. The HCDE courses consisted of both HCDE research credits and a formal class on Human-Computer Interaction (HCI); the CSE courses were special topics credits and a senior capstone course. The course sequence was co-taught by two instructors, one from each department.

Table 1. Details of each quarter of the course sequence

	Autumn	Winter	Spring
# of students	17	13 CSE; 22 HCDE	12 CSE; 10 HCDE
# of credit hours	1 credit	2 credits for CSE 5 credits for HCDE (HCI class)	5 credits for CSE (capstone) 2 credits for HCDE
Departments represented	CSE, Informatics, HCDE	CSE, HCDE, Informatics, Psychology, Art	CSE, HCDE, Art

Autumn Quarter

In autumn quarter, students in a seminar read and discussed research papers about projects in developing countries and resource-constrained communities within developed countries (i.e., low-income communities, homeless populations, low bandwidth environments). The purpose of this seminar was to familiarize students with unique constraints when designing for resource constrained environments (e.g. How do you design for cultures where people are unfamiliar with or afraid of technology, or for environments where power and network connectivity are scarce and expensive?). The course met one hour a week, and a different application area or design constraint was discussed at each meeting. Sample topics include education[21], transportation[22], non-literate user interfaces[23], designing technology for homeless populations[24], healthcare[25], and agriculture[26]. The full reading list can be found on the course web page[27]. Students were appointed to lead the discussion and record notes. One limitation of the three-quarter structure is that few students enrolled in the entire sequence, and we did have significant attrition between autumn and winter quarters.

Winter Quarter

Winter quarter was a group project design studio. Students who enrolled in a five credit HCI course offered by the HCDE Department were partnered with CSE students registered for a two credit design studio. Project groups were organized around student interests, and each group consisted of both CSE and HCI students. On Tuesdays, all students met together (CSE and HCI students), and topics relevant to the group project were discussed (reading related to resource-constrained communities, selection of project topics, group work skills), and group presentations were given to the class. On Thursdays, only the HCI students met; during these sessions they discussed fieldwork and HCI-focused topics. In addition, most weeks the instructors met with each group individually for a half hour to discuss progress and issues specific to that group.

There were seven project groups with approximately two CSE students and three to four HCI students per group. Within the project groups, HCI students were responsible for doing needs analysis through fieldwork, literature reviews, and social impact analyses to lay project groundwork. HCI students did fieldwork in a variety of domains and scenarios including: interviews with doctors and medical students at local medical clinics, observations of food bank operations and elementary school classrooms, web surveys of potential carpoolers, and email surveys of Ugandan midwives. CSE students were responsible for coming up with initial prototypes for the technology and discussing technical specifications with the group. Throughout the course, student groups gave presentations to the class, and at the end of the quarter a poster fair and demo session was held for the general public.

Spring Quarter

In spring quarter, CSE students enrolled in a five credit capstone and were partnered with HCDE students who signed up for two credits of directed research. CSE students built robust prototype implementations of the designs developed in winter, and HCDE students helped evaluate the prototype through user testing. Throughout the quarter, student groups presented their ideas to the class and to panels of experts in formal presentations, poster sessions, and written reports. There were a limited number of full class meetings; instead the instructors met with each group for a half hour each week to discuss progress and issues specific to that group. The class as a whole met three times during the ten week quarter to select project groups and to give presentations.

In order to complete the required implementation and to provide a group software development experience, each group was assigned about four CSE students. Three of the projects from winter quarter were selected to continue into spring; they were chosen based on student interest and progress made in winter. Each continuing project was selected in part because of the continuity of student enrollment. Some groups had most members carry over from winter; others had several new members join the project at the beginning of spring quarter. Some of our outcomes discussed later can be framed against the backdrop of team coherence and consistency.

Student outputs varied based on the number of credits for which students were enrolled, but all group project teams were comprised of students from multiple departments. In the spring, the only formal assignments were the final prototype, paper, presentation and poster. All students contributed to the presentation and poster based on their project contributions.

Course Projects

Winter quarter course projects ranged from relatively cleanly-scoped local projects (design intake and inventory software for a local food bank) to open-ended international collaborations (help an existing program train midwives in Uganda to use ultrasound more effectively). Each of these projects provided some concrete findings for instructional design.

Project topic areas were:

1. Food Bank software for tracking inventory and donations
2. Ridesharing for our geographical area
3. Making an existing mobile transportation application (OneBusAway.org) useful for low resource communities
4. Turn a mobile phone into a doctor's office
5. Make ultrasound more usable by midwives in Uganda
6. Adapt an existing application (ODK Collect[28]) to support data collection for medical exams
7. Create local opportunities for a multiple-input educational interface (MultiLearn)

Three of these projects continued into spring quarter: Ultrasound, Adaptable interface to support medical exams, and MultiLearn. Below we discuss MultiLearn and Ultrasound in more detail to give the reader an idea of the type of projects students worked on.

MultiLearn

The MultiLearn project team took on a local design challenge. Their goal was to take a system that allows multiple users to interact with one computer that had been developed for and tested in India[29] and adapt it to local educational settings. The MultiLearn system works by allowing multiple students, each with their own USB keypad, to share a single computer and interact via educational games. Most of the schools in Seattle have only a small number of computers in each classroom, providing a daunting challenge for teachers who want to find ways to use them productively with students. Their project was to find out what kind of educational and assessment work would be useful to the target population and how to implement that given the hardware and software available in most schools. In winter quarter there were two CSE students and four HCI students on the MultiLearn team. In winter quarter, students visited local Seattle-area classrooms, interviewed local teachers, reviewed educational software including games, did multiple classroom visits across various school districts, assessed the state of computing instruction and resources in elementary schools in these school districts, and talked with elementary age students about their use of the computers in the classroom.

In spring quarter, four entirely new CSE students took over this project, and one HCI student dropped out bringing the total to four CSE and three HCI students. In spring quarter the group developed a prototype interface for use by local teachers that would allow teachers to track individual student progress on educational 'games,' see how students overall are performing, and eventually share information on individual student performance and progress with parents. They also built a web-based interface that would allow teachers to create their own content. Students built content for math games and brought the system to one elementary school classroom for testing. This group was characterized by a new set of CSE students in spring quarter who had varying backgrounds, conflicting individual schedules making scheduling meetings difficult, and challenges building on the success and code base of a project designed for use in the developing world. In part, some of the challenges were tied to lack of commented code, and issues in making older code work on newer platforms. Because the original developers were no longer students, their availability to talk to the students working on a newer version was limited. A series of communication breakdowns characterized this group throughout, and the lack of project outputs moving forward is in part a reflection of those difficulties.

Ultrasound

The Ultrasound project was the result of one of the instructor's conversations with a professor in Radiology who was training midwives in Uganda to use ultrasound technology. They were having some issues with the commercial portable ultrasounds (cost, difficulty of user interface, etc.), and so the problem posed to the students was: how can you make ultrasound more usable by midwives with limited training? And can you make it cheaper, too? In winter quarter there were two CSE students and three HCI students on the team. In winter quarter, students surveyed Seattle-area midwives, created surveys to send to Ugandan midwives, investigated other developing world based maternal ultrasound projects, conducted a literature review for maternal ultrasound, met with local radiologists and ultrasound technicians to learn about ultrasound technology, contacted major ultrasound manufacturers to find a less expensive technology that would be viable for the purposes of the project, and tried to form bonds with local immigrant communities to involve them in the work. They also conducted a social impact analysis of ultrasound, and they analyzed the data they collected from their multiple stakeholder interviews. Other than the initial contact with the professor in Radiology – and the link to the midwives in Uganda with whom he was working – the students had to find all of their local connections for fieldwork. They took significant initiative in contacting both NGOs conducting ultrasound-related work, and ultrasound manufacturers, eventually finding a salesperson who could refer the team to an ultrasound probe on campus they could use for their project. In addition, the students registered themselves as a student organization to allow for future fundraising, and they applied for a capstone award from the College of Engineering (which they won).

In spring quarter, two more CSE students and one HCI student were added to the team bringing the total to four CSE and four HCI students. In spring quarter the group obtained an ultrasound probe and sample control software, and implemented a prototype interface designed for use by Ugandan midwives. They continued to design the help system, and they did user evaluations with local ultrasound technicians and radiologists. This group was characterized by a highly motivating problem, great group dynamics, an unfamiliar and remote user population, and an interesting technical challenge. There have been multiple positive outcomes moving forward from this project. Four of the original students continued their work on the project outside of the course and remain active today. In March 2011, three of these students will be going to Uganda to do a preliminary evaluation of the project with midwives. The fourth student will go with a larger group in June. Since spring 2010, several other students and doctors have joined our team, we have published multiple academic papers (all with student authors), and in October 2010 we were awarded a Bill and Melinda Gates Foundation Grand Challenges Exploration grant.

Lessons Learned

Of the seven projects from the class, one has continued with significant success. Others provided the groundwork for other developments (that discussion is outside the scope of this paper). Overall, we consider the class a success, and student feedback concurs – but that success does not come without costs. Our goal in this paper is to better define what we mean by 'success,' provide clear description of the drawbacks and overhead of such a class, and demonstrate how our lessons learned can inform other, similar attempts at curricular innovation.

We conducted official end of course evaluations for the students enrolled in the winter HCI course, and for the CSE students enrolled in the spring CSE capstone course. In addition, throughout the year we conducted our own informal web-based evaluations of all students: in the middle of all three courses and at the end of the winter and spring courses.

Overall students in the winter HCI course reported high satisfaction with the class. On the official end of course evaluations, of the 18 students responding, 3 rated the course as a whole as "excellent-5", 9 as "very good-4", 5 as "good-3", and 1 as "fair-2" on a scale of 5-0. Of 19 respondents to a question about the relevance and usefulness of course content, 7 students rated the course as "excellent-5", 6 as "very good-4", and 6 as "good-3". CSE students also evaluated the spring capstone course positively. On the official end of course evaluations, of the 12 students enrolled in the course, 6 rated the course as a whole as "excellent-5", 4 as "very good-4", and 2 as "good-3" on a scale of 5-0. Seven students listed the amount they learned in the course as "excellent-5", 2 as "very good-4", 1 as "good-3", and 2 as "fair-2".

Based on the multiple data sets collected by the instructors throughout the class, a clear pattern emerged that what students found most exciting, challenging, and beneficial from the class was (a) the fact that they were working on real world problems, and (b) that they learned to work in truly multidisciplinary teams that are likely to reflect real workplace situations.

Real World Problems and "Strange Surprises"

The value of having students work on real world problems is well established in the literature[30]. Our students were no exception. When asked what advice they would give a student from their major thinking of taking the course next year, one CSE student had this to say about the winter course:

“definitely go for it! it's an experience way different than any of the standard cse courses. you actually get to apply your knowledge to real-world issues which is very rewarding”

Repeated over and over by both CSE and HCI students, was the perceived benefit of the real world component of their projects. “It was a real problem, not a made-up one,” said one student. [HCDE student, official end of course evaluations, winter 2010] Additionally, the “real-world project” was identified by students as one of the aspects that most contributed to their learning. In addition to the resonance with service learning and the usefulness of demonstrating the global impact of engineering innovations, real world projects require students to venture outside the university and encounter people who are not like them. Projects designed for resource-constrained environments are particularly likely to lead students to encounter new viewpoints. This clash of cultures can be both destabilizing and also enriching. As one student described the class:

“There was a lot about design that I hadn’t previously taken into account. Now I take others’ points of view into account, and enjoy the strange surprises that that yields. [HCDE student, official end of course evaluations, winter 2010]

These strange surprises are one of the elements of projects that tie students to their larger communities. They are also, it turns out, a byproduct of teams that are truly multidisciplinary.

Multidisciplinary Teams

The student quotation in the above section about the “strange surprises” of the course can be read as a student encountering resource-constrained communities close-up for the first time. Seeing how other people use technology and navigate their everyday lives can open students up to new models of design and innovation. However, this quote can also be interpreted as a lesson learned about taking into account the views of other *students*, particularly those from other departments.

One of the strongest themes that emerged from the multiple layers of student evaluation for this course focused on the difficulty and rewards of the cross-departmental group work. Students grappled long and hard with the knowledge gaps among themselves. Most of the comments, however, talked about the usefulness of such struggles, and the uniqueness of that learning opportunity. We would also argue that one of the strengths of this class is that the challenge of the multidisciplinary team better prepares students for the workplace than more common teamwork assignments among the same majors. As one HCI student commented, “I think this is a great idea. It gives you more experience working with real "SME's" [Subject Matter Experts] and combining skill sets, as you do in the real work place, as opposed to getting used to just working with people who are trained to see and do the exact same things you do and not being prepared for the work place.” That is the other category of “strange surprises” from the class – learning to learn and learning to teach across expertise boundaries.

Students seemed to value the interdisciplinary nature of the project groups, even when group dynamics were challenging. On a spring end of course web survey, four of the eight CSE students responding (out of 12 CSE students enrolled in the course) mentioned the interdisciplinary nature of the groups as an aspect of the course that contributed most to their learning. In particular, they called out the multidisciplinary team as an opportunity to deepen their own learning. Learning to explain technical details to others, students expressed, led to learning things more deeply for oneself:

- "In CSE classes there's a very serious tendency to just completely ignore design considerations. After all, if you're the only one using this program, who cares if you have to call it up from the command line with several switches? Ease of use is totally secondary to efficiency and accuracy. Working with an interdisciplinary group both forces you to think about design considerations and also forces you to explain technical topics to someone who may not fully understand what you mean (which helps you understand them better)."
- "It felt more like a real-world project that would happen in the work-place, and it was an enjoyable experience to be able to work with different majors. Sometimes, there are CSE elements that are a little harder to explain to others, but discussing at a higher-level, other majors can understand as well."

Students also provided reflections on differing kinds of expertise and how they developed through the course an appreciation and ability to value others' skill sets. CSE students noted:

- "Working on teams together with the HCDE students helped broaden my perspective."
- "Working with an interdisciplinary group was extremely insightful. To be perfectly honest I thought design was something that was just done using intuition - I had no idea there was so much rigor involved."
- "This was a really good aspect of the class. I felt like I learned a lot about designing UIs and user research by actually doing it with people who have that background."
- "Awesome. I was very happy to learn design concepts along the process of using my programming skills."

HCI student comments included:

- "This was really nice because we all had different backgrounds--really nice!"
- " It's always great to work with people with different perspectives and skills."

Along the same lines, it is particularly interesting to hear CSE majors comment on what they learned during the winter quarter course (from our web survey, in response to "What did you learn in this course?"):

- "I learned a lot about the usability-side of developing technologies through field work, discussions, readings, etc."
- "How to work with people from different majors"
- "How to effectively split work among team members"
- "How to do user testing"

- “Mostly, I learned what the dynamic was like in a interdisciplinary group such as the one I worked with, and how to manage and cooperate to reach towards a similar goal.”
- “Fundamentals of design and HCI, how to interact with non-CSE students.”

These signs of deep struggle and great success in working with people from different areas of expertise is one of the most innovative and promising elements of this course sequence. It is also, however, one of the characteristics that requires careful instructor intervention and a considerable amount of instructor overhead. If the above discussion was all about the best outcomes of the class, the next paragraphs make clear the significant resources necessary to generate such outcomes.

Managing the Class Cohort

In winter quarter, with the exception of a couple of students, the CSE students were not enrolled in the 5 credit HCI course. They took a 2-credit special projects course, and both sets of students met together on Tuesdays while the HCI students met on their own on Thursdays. In our feedback surveys, several of the CSE students expressed that they felt like they were missing out on things that happened in the HCI course on Thursdays. (Although CSE students were welcome to attend on Thursdays, few did so.) This became particularly acute later in the quarter when Thursday sessions were devoted primarily to project work; we attempted to address this by having one HCI student from each group send an email to the entire group at the end of each Thursday class meeting, giving a summary of what happened that day. A few students from the HCI course commented on the problem and our solution:

- “I think there were aspects of the format that worked and aspects that were problematic. On the positive side, I think it was practical to only have the CSE students there one of the two days because half of the time was definitely focused on content that wasn't very relevant to them. But on the other hand, I know that many of the CSE students felt a certain degree of detachment from the projects as work was being done with them "out of the loop." While the requirement of the [HCI] students sending out update memos that was instituted partway through the quarter mitigated this somewhat, it couldn't completely eliminate the fact that the separation led to the CSE students seeming to be less invested in the projects.”
- “I feel like the CSE students were less involved and were unable to contribute a lot of the time because of things they missed during the second class meeting. The weekly half hour meetings were great for answering questions and keeping the projects on task. More time in class to learn about the procedures would help so that we were more prepared for our actual studies”

As an additional strategy, a few weeks into the winter quarter we instituted weekly meetings with the entire project team for each group. This was a considerable additional instructional commitment, but also proved absolutely essential for building cohort cohesiveness given the differential classroom contact time across the two groups of students.

In a parallel development, in spring quarter, two out of eight CSE students responding to our end of course web survey mentioned that the fact that the CSE students were registered for 5 credits and the HCI students were registered for 2 credits in some cases led to less involvement by the HCI students.

For the most part students thought the format of the spring course (a total of three whole-class meetings and weekly half hour individual group meetings) was effective, although a few expressed interest in longer meetings with the instructors each week. When asked specifically about the course format in spring, four out of the eight CSE students responding to our web survey said they wished there had been more time for the instructors meeting with individual groups each week; the other four thought the amount of meeting time was sufficient. These half hour weekly meetings occurred throughout both winter and spring quarter, and required the attendance of both instructors and all members of each group. Although the groups needed and appreciated this level of personalized multidisciplinary guidance, scheduling meetings was sometimes a challenge and represented a significant time commitment on the part of the instructors. Any discussion of scalability or replicability of this kind of class needs to acknowledge the amount of instructor time commitment required to manage the delicate balance of multiple credit hours and multiple majors involved in groups. We would characterize this as a high risk-high reward type of teaching situation.

An additional problem faced by the sequencing of the course was the issue of continuity from term to term and within project teams. We observed several issues related to group coherence when new members joined a team already in progress, and this is clearly an issue for further research. This is an area where teamwork more closely resembles the workplace with employee turnover, but we have yet to develop effective instructional strategies for managing these kind of cultural shifts within learning groups.

Guidance for Student Projects

As instructors, we also learned several specific things that are informing our future course offerings. Because this kind of design studio forces students to work with communities that may be far from their everyday experience, and with classmates who may not share a common vocabulary, they need specific kinds of scaffolding that aren't necessarily required by other project, capstone, or even service learning opportunities. Specifically, we found that group success was more likely when we:

- Provided student groups with an accessible end user population
- Provided student groups with an outside expert/client who was responsive
- Scoped projects so they presented a technological "sweet spot" with challenges that were significant enough to be interesting but yet not paralyzing
- Provided guidance and guidelines for how to accommodate changing group members and dynamics

Resource-constrained Design as an Area for Student Projects

The idea for this course was based on a CSE capstone course on information and communication technologies for development offered in the two previous years[11]. Projects in those courses were more focused on communities in the developing world. In order to provide more reasonable opportunities for field work, for our course we defined resource constrained environments to include local resource-constrained communities (low income, homeless populations). Selecting problems from this area not only provide highly motivating and potentially humanitarian projects, but they also expose students to a set of design constraints that they are unlikely to have encountered in any previous engineering course. Whether designing technology for midwives in Uganda or local low income or homeless populations, students are forced to consider issues such as:

- **Very Low cost –** Cost has implications beyond market share (and obviously takes on a new meaning in scenarios where people live on less than $2 a day). Expensive computing devices are at risk of theft or can even put their owners in personal danger. The fact that design in resource-constrained environments inherently relies on the use of low-cost technology can be a benefit when trying to secure resources for student projects.
- **Low power –** Although students will probably be familiar with the idea of conserving power for environmental reasons or to extend portability of devices, they are not likely to have designed for an environment where power is intermittent or relatively expensive or both.
- **Low connectivity –** While cell phone coverage is becoming more and more available worldwide, Internet coverage is still far from universal, and continues to be expensive.
- **User interface challenges –** Most students have never designed user interfaces that need to be accessible not only to people of different languages and cultures but also to those who are illiterate or who have a fear or distrust of technology. Cultural sensitivities add another dimension.

Conclusion

The overall goal of this class – to give students a capstone experience that provides real-world projects and introduces them to deep and difficult multidisciplinary teamwork that prepares them uniquely for the workplace – is ably coupled with the topic of designing for resource constrained environments. Spreading the course over multiple quarters also gives students the opportunity to engage with multiple stages of the design process, including ideation, fieldwork, design, implementation, and evaluation. The comments from students as well as evidence provided via projects living beyond the course provide a persuasive argument that the course approach is generally innovative and successful.

Our approach is also somewhat unique in combining two domains that may be more likely to not understand the depth of each other's skill sets, coming from disciplines that tend to attract different types of students with varying work approaches. In that sense, the domain of resource-constrained environments is an extremely well chosen area for this kind of experimental multidisciplinary learning experience; the design challenges in this space, as mentioned earlier, are complex, and the human-centered challenges are as complicated and rich as the computing-centered challenges. From an instructional standpoint, then, if we can unite both of these types of challenges with a motivating real-world problem, we can create opportunities that allow diverse groups of students to pull it all together and create great things. Students gain a multitude of skills, as well as unique preparation for the workplace where they will often have to interact with people from varying backgrounds and with skill sets far from their own.

However, such a teaching approach is not without costs or drawbacks. As discussed earlier, managing the culture clash between the departments required regular meetings that both instructors attended with all group members, and the amount of individualized feedback to each group exceeded that of a typical project-based class because of the need to manage the different kinds of contributions made by students. Other elements of our class that contributed to its success that we have not discussed at length here but are worth mentioning as part of the time commitment include:

- Conducting a “pre-class” reading seminar as we did in fall quarter to introduce students to work in the field is valuable and provides an important shared vocabulary and common background for students to use in scoping their own work. However, the logistics of scheduling such a class, recruiting students, and ensuring some measure of continuity from term to term is challenging
- Picking projects is among the most important pieces of the puzzle. Choosing projects that are of the correct scope can be challenging, but a course like this requires other careful considerations including:
    - Ensuring that each student group has access to a real client who has a stake in the project and is responsive to students
    - Ensuring that each student group is dealing with an accessible user population that they have the skills to reach via fieldwork activities
- Assembling student groups with the correct range of skills is key. We had students list their own skills, classes taken, skills they want to learn, anything they want to avoid, and then rank their top several projects. The instructors then used that information to create groups.
- Having students present their work to communities outside of the class reinforced the real-world nature of their projects. We had students present to a public seminar on campus and conduct a public poster session. Both of these experiences provided students the opportunity to receive feedback from a community outside of the classroom environment. The poster session in particular was successful at attracting attention for the course and work in this area. In addition, having the posters available means they can also be used as a general recruitment tool for engineering students. Similarly, demos of these projects done by students themselves can also be a productive outreach activity.

As we have discussed throughout this paper, our approach in creating a course to bring together teams of students from multiple disciplines yielded promising results from an instructional standpoint, responded to ABET recommendations, and gave students some unique preparation for the workplace. Students worked on projects with real-world impact and gained valuable experience with multidisciplinary design and multidisciplinary teamwork. Both sides gained a greater appreciation of the difficulties faced by their peers – that fieldwork and software development are both often unpredictable and challenging. The course also demanded a large time commitment from the instructors, but the rewards were significant enough that the course is being offered again. There are some slight changes to this new offering, in part reflecting shifts in the cultures of the participating departments, but we look forward to the results from this second offering and learning from students’ experience with the multidisciplinary challenge of this capstone experience.

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