Partnering with Social Service Organizations to Develop Socially-Relevant Projects in Computer Science and Engineering

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Abstract *— The University at Buffalo's Computer Science and Engineering (CSE) Department is partnering with the Center for Handicapped Children (CHC) and Elderwood Healthcare to solve socially relevant problems through service learning in its capstone design courses. Such projects have long been used in the social sciences and health professions to provide students with real-world experience. In computer science and engineering such problems are typically viewed as too vague and outside the mainstream to be considered reasonable for students. However, the design of systems directly for use by the handicapped starting from an incompletely specified problem serves as an invaluable learning experience. The use of socially relevant projects contrasts with traditional well-defined problems with fairly direct solutions. Choosing a problem that is not within the experience of most students forces them to develop a high-level understanding and design before coding, as early implementation is not feasible. Clients, such as health care providers and handicapped individuals, rarely understand the capabilities of technology, cannot assess the complexity of desired features, and do not use the same vocabulary as CSE students. Through this experience students learn to view project requirements and constraints from the domain of the client. Student teams elicit project specifications and constraints from clients, and are responsible for effective communication of design capabilities and complexities back to the client so they can make educated product decisions. For students these projects cease to be purely academic exercises and become problems that required their full creative and cooperative energy. When exploring sources for projects the handicapped community had a wealth of unsolved and technologically complex problems. Partnering with these groups became a win-win experience. Not only does CSE provide much needed technical solutions, but students begin to see themselves as having the power to make a difference, responding with intensity and philanthropy. Clients have participated in the classroom experience as recipients and teachers. The program has rescued students at academic risk, broadened our students' understanding of the needs and experiences of special needs individuals, exposed them to dealing with real-world clients, enhanced the school's reputation, and delivered much-needed devices.*

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Index Terms *— capstone courses, service-learning, software engineering, socially relevant projects.*

1. BACKGROUND

After 12 years of a "traditional" approach to team projects (building simulated ATMs, Mars landers, human resource programs and such), faculty members at the University at Buffalo decided to involve student teams in projects outside of the university, in the community, to build systems that might actually be used. The target client base we selected were organizations serving the handicapped, medically frail and technologically dependent. Our objective was twofold. First we wanted to use projects that would engage our students, to harness their creative energy and provide them with a reason to stay "tuned-in" through two semesters. In addition, we felt that CSE students would benefit from the broadening experience of working with individuals whose quality of life could be improved through the use of the very technology our students take for granted. Second, through service, university students would have the opportunity to leave their imprint on the community after they graduated. Clearly the service learning model so widespread in other disciplines could be applied to meet our goals.

In the Fall of 2002, students were asked to build an augmentative communications device for a 43-year-old stroke patient who had limited motor skills. While there was no cognitive impairment, he was confined to a wheelchair and unable to speak. The best features from the resulting projects were assembled into a single device donated by Microsoft Corporation and given to the client. He uses it today as his main means of communicating. In the Spring of 2003, we reassigned the project with new requirements from CHC to meet the needs of children with cerebral palsy and other severe disabilities. The device needed to be useful to youngsters with and without reading skills. Special requirements were written to include children with visual impairment. In Fall 2003 and Spring 2004, we responded to another request from CHC to design a teaching station for severely handicapped students which provides a multi-sensory light and sound experience, to facilitate the teaching of choice-making in physical and occupational therapies.

2. PROBLEMS WITH A TRADITIONAL APPROACH

Assigning closed, well-defined projects, regardless of their application outside the classroom, do not engage the students to the degree necessary to accurately simulate the real world. More time was spent by students anticipating the intent of the instructors (and hence, the grading criteria) than deriving real customer requirements. The prime motivator in the class was still the grade they received rather than what they could learn. While historically our students were always engaged in their capstone projects, even projects with real on-campus customers lacked the need for creativity and understanding we desired. While students found the team experience rewarding, the value of the course was seen more in hindsight, once they were on the job rather than during the semester. Only students who had real work experience saw the relevance of the lectures and the team project.

Capstone design courses based upon university-industry partnership are a bit more open-ended and somewhat more successful than strictly in-class involvements. The University of Washington has found that industrial involvement in the project activity raises the interest and performance of students. [9] Industrial partnerships have a number of limitations: not all universities have such partnerships easily available. Where available, such industry partners are not likely to turn over large, complicated, important projects to temporary student help. And most significantly, industry partnerships did not offer the potential for students to get personally committed with or form an emotional attachment to a cause. In most academic environments grades (and we would hope learning) are the students' primary motivator.

Additionally, our department serves a large number of students in its capstone courses and multiple sections are offered. While we strive for consistency across sections, each faculty member brings individual strengths to their teaching. Providing similar classroom environments in lectures, class discussions and group dynamics can be difficult, especially in classes of 60 or more students and multiple professors. Again, we looked to the class models in the social sciences and health professions for one that would better serve our students.

3. BACKGROUND RESEARCH ON LEARNING IN COMPUTER EDUCATION

Research on instruction in Computer Education reveals that curricula resulting in a high level of student comprehension, internalization, and retention have five fundamental elements:

- design projects take place as real-world experiences [12];
- students have high level of motivation early on in the course;
- students have available rich design environments (e.g. [4]);
- many possible solutions exist to the problem presented; and
- academic evaluation builds upon previous learning.

All five of these elements, however, are rarely found together in a capstone design experience, which is acknowledged to be critical in undergraduate preparation in Computer Education (ABET 2000, [11], [2]).

Many capstone Computer Science courses utilize problem approaches that are paradoxically too well-designed for effective learning. The problems, while taken from the real world, such as the ATM, Mars lander or library information system, do not mimic closely enough the state of design problems that computer scientists and engineers will face in the marketplace. Truly real-world problems, such as those engaging students in internships, cannot easily be brought to a cohort of 80 to 200 undergraduate majors (cf. [7]). While high levels of student engagement and intensity can frequently be found in courses carried out as small-group, one-time 'advanced' courses (see [8]), such courses are hard to recreate, are exhausting to faculty, rely too much on the enthusiasm of the faculty, and do not translate well into required majors' capstone experiences. Rich design environments at the university or college site are not cost-effective and cannot be refreshed unless they are used by most of the graduating cohort.

We have found that, through service-learning, capstone courses can be effectively taught in a learning environment of:

- very high student motivation and engagement;
- very challenging material;
- very high level of instructor expectation;
- rich design possibilities.

4. SOCIAL RELEVANCE AND SERVICE LEARNING AS A COMPUTER EDUCATION EXPERIENCE

Our capstone design sequence involves the construction of complete systems motivated by socially relevant needs. Socially relevant projects, or service learning have long been used in the social sciences, education and health-related professions to provide real-world experience, or practicum.

According to the Campus Compact, "service learning improves student learning, addresses community needs, facilitates public debate and dialog, and creates campuses that are true partners with their community."[1] Surveys of American universities in 1998 [6] and 2000 [5] found that despite active and successful internships and placements of engineering students only a small percentage of these cooperative ventures involve service learning. Where service learning does exist, as with EPICS programs begun at Purdue University [3], most projects serve the needs of community agencies by providing low cost application of known technologies "for the delivery, coordination, accounting, and improvement of the services they provide." [3]

Within the United States, engineering programs such as EPICS, begun at Purdue University, partner with and provide service to organizations such as Habitat for Humanity International, the Red Cross, Salvation Army, and a variety of other social and educational organizations that support those in need [3]. Internationally, programs such as those at Villanova and Marquette utilize service learning to provide building construction for orphanages in Honduras, and build bridges, water and sewage facilities and assist in medical clinics in other countries in Latin America. Other programs provide software that maintains documentation for war crimes in Kosovo [10] while others assist communities in China. Despite the obvious need for engineering support in the developing world and considerable needs within the United States, and the clear educational benefit to students who engage in these projects, service learning is infrequently explored in engineering.

In computer science and engineering service learning projects tend to be viewed as too vague for students to understand. However, the design of a complete system starting from a vague, ill-defined, or incompletely specified problem is an invaluable educational experience and is exactly the sort of problem practitioners face. Real-world problems are by their nature ill-defined.

The use of socially relevant service learning projects in our capstone sequence contrasts with traditionally well-defined problems with fairly direct solutions. Choosing a problem that is socially relevant and *not* within the experience of most students forces students to develop a high-level understanding and design before coding, as early implementation is not feasible. Clients such as health care providers and handicapped individuals rarely understand the capabilities of technology, cannot assess the complexity of desired features, and do not use the same vocabulary as CSE students. Through this experience, students learn to view project requirements and constraints from the domain of the client. Student teams elicit project specifications and constraints from clients, and are responsible for effective communication of design capabilities and complexities so they can make educated product decisions. For students these projects cease to be purely academic exercises and become problems that required their full creative and cooperative energy.

5. Creating an Experience that Works

Students in capstone computer science and engineering courses tend to think in terms of "coding a solution" and it is very difficult to focus their energies on customer requirements and design. Given the nature of the problems we choose students are forced to focus on understanding customer requirements and developing a high-level design before they can "think code." While students at first complain that they do not inherently understand the problem and are unfamiliar with the customer's environment, this is precisely the point. By working with non-technical clients such as health care providers and the disabled on their own students are forced to immerse themselves in the problem domain. Thus students find it hard to begin coding or implementing the solution prematurely, without careful thought, planning and serious client-developer interaction. Professionals in a caregiver role are often impressed with the quality of life improvements that can be provided once they understand the options.

Perhaps more importantly, students almost immediately come to see their work as important. Students expect capstone projects to be "cool and neat." With socially relevant projects students indicate that they experience something more. They see the work they are doing as having the potential to "help someone else, something that assists somebody." The prospect of making a difference not only engages their attention but also sustains and motivates them through the weeks and months of design, implementation and coding. Equally importantly our social-service clients receive more than just a technological solution to a problem. They too are energized as they see their "dreams" take form. They also see themselves as opening the intellectual doors for university students into the lives and world of the disabled. Our partners come away with a better understanding of the real potential of technology and our students see in themselves the power to truly improve the quality of life of others.

The problems we solve focus on developing technologies that improve the quality of life and education opportunities for severely disabled clients. Our goal is to provide technology inexpensively that can potentially and easily be adapted to provide similar support to others within the target population. Unlike other projects for the disabled [4] we are not adapting existing devices, by e.g. modifying children's toys for disabled youngsters or building specialized furniture for the visually impaired. Rather we are providing low cost solutions to persistent problems common to the individuals in nursing facilities and educational devices to be used with students too disabled to be mainstreamed into a regular classroom.

On a more technical level, the projects we have used in the past four semesters have involved the development of assistive technologies for disabled individuals. Students have developed a voice communications device for an adult without vocal ability in the first semester, and adapted it for use by children in the second semester. The third and forth semesters, students designed a sensory-feedback learning device for teachers and therapists to use in teaching choice making and cause-and-effect to severely handicapped youngsters. The nature of these problems is such that they have no clear and obvious solutions. There is a large space of possible solutions involving both hardware and software from which to choose. Students quickly come to realize that there is no one correct solution, but rather many paths to solving the problem. Some students find this notion disturbing. "What do you mean, that there is no *right* solution?"

In our approach, only a basic description of the problem is provided and students are required to develop a complete specification on their own with faculty guidance. Classes are grouped into teams of 6-8 students, and each team develops its own implementation. Our laboratory contains a selection of hardware components and development workstations – a rich design environment of choices. Yet, in reality the world is our laboratory. Students are encouraged to make trips to visit clients at their facilities. They are encouraged to explore and seek out existing solutions to similar problems and where appropriate adapt them. If a component is open source, they are encouraged to give appropriate attribution and use existing code. If affordable, students can sometimes purchase the items needed. We discuss code reuse and students are advised not to reinvent the wheel. The shortness of time forces this message home.

From the perspective of a capstone design course, these projects harness a broad cross section of material from the computer science and engineering curriculum: novel multi-media user interfaces, scripting languages, event-driven programming, device drivers for controlling hardware, software engineering issues, including requirements derivation, client interaction, sensitivity to the delivery culture, hardware/software integration, and "catalog engineering" (sampling the industry and choosing the right parts).

Just as we altered the learning environment, so too did we alter the teaching model. In order to best supervise 25 or more teams per semester, coordinate with clients and provide lectures that are consistent across sections we evolved into a team teaching model. Three faculty members and periodic guest lecturers merged their strengths. We coordinate out teaching across the semester so that the same faculty member gives the same lecture to all sections. Since we each teach the topics we feel most passionate about, our interest is infectious, better engaging the students. Since we rotate our teaching, students are never "stuck" with any one of us.

6. THE THREE PROJECTS:

Fall 2002 – An Augmentative Communications Device

This effort was based at a skilled nursing facility, Elderwood Healthcare in Amherst, NY, and centered around "David", a 43-year-old stroke patient with limited motor skills, full cognitive capacity, but an inability to speak. David is in a wheelchair. Students were asked to use commercial grade technology (laptop computers) to create a menu-driven means of selecting words and phrases that might enable David to communicate. The key to the software capability was context-awareness, phrase completion, and an evolving intelligence that prepares responses in anticipation of choice. The goal was to make the device easier to use over time, for individuals with gross and fine motor impairments. David visited our class, and students visited David in his residence. Despite the seeming complexity of the task, all the teams produced a working "talker". In the following semester students who wished to carry this project forward took the best of the class systems and assembled them into a single unit, added some additional features and, with the donation of a tablet PC from Microsoft Corp., gave David a "talker". He uses it as his main means of communications.

On the night he was given the prototype device by a student team, he spontaneously used it to telephone one of the course instructors, and carried on a slow but discernible conversation. He had not used the phone in 20 years.

In watching David, it was clear how just a little technology went a long way to improving his quality of life. Involvement with a student project team was a welcomed experience for David and his family. Staff at the facility where David lives have responded with enthusiasm and cooperation.

Spring 2003 – An Augmentative Communications Device for Children, and the Visually Impaired

Students were asked to produce a child-centered version of the Augmentative Communications Device, with heavy reliance on graphics and auditory feedback. Devices for this population were expected to use menu items more catered to a child's home and school environment.

The Center for Handicapped Children's (CHC) Learning Center in Williamsville, NY graciously offered to serve as a specification and testing facility, including the use of its client base, faculty, therapists, nursing staff, administration, and equipment. Their participation ranged from simple non-intrusive observation of their students, to selecting a child to serve as a target client. The children at the center are often medically frail and technology dependent. Their communications skills vary, but the school is a rich setting for adaptive technology and augmentative communication. Targeting children posed a unique set of problems and opportunities for the instructors and students in this course. Student-developers of devices in this class had to consider auto scan and single switch menu selection, the varying reading skills of their student-clients, varying gross and fine motor skills, and visual and audio impairment.

We found it necessary to address the emotional and psychological impact of severely handicapped clients on our own students. It was made clear to the teams that not everyone was expected to visit the Center and that we understood that some of our college students would be uncomfortable. By taking a video of our visit, we were able to provide students who were unable to visit the Center with a sense of their client population. Just as with David the semester before, some students were super-charged by their visit to CHC. Suddenly they were working on a project that could make a real difference to real people. These individuals regularly found themselves advocating for their clients to ensure that the devices developed were truly useable. The child version of the augmentative talker is in a deliverable but prototype state. We are fine tuning it to the needs of a few select students.

Fall 2003 and Spring 2004 – The "DISCO" System

The objective of this effort, was to provide a programmable light and sound station, for therapists and teachers to use when teaching choice-making and cause-and-effect relationships to physically and developmentally impaired children**.** Utilizing light, music, and sound (including music and spoken-word), the station helps therapists and teachers create a positive feedback, or a calming environment for students who react positively to enhanced sensory experiences. The clients and customers are the teachers and therapists. The users are the handicapped students. The system keeps statistics on successes and failures during use, so that teachers can alter the experience, and use it as part of a child's Individual Education Plan (IEP).

In both Fall 2003 and Spring 2004, the Center for Handicapped Children's Learning Center in Williamsville, NY allowed us access to their facility for student tours and interviews. Therapists and CHC youngsters visited our classes. Videotaping of the teachers, therapists, and children again occurred. CSE students in the Software Engineering course immersed themselves in the client environment as much as possible. The enthusiasm of CSE student teams for helping handicapped children through the use of stage lighting, fog machines, fiber optics, water, sound, music, video and bubble making was overwhelming. Some students went so far as to purchase equipment on their own and acquire donations to build systems.

The best ideas were combined into a prototype system that was delivered in June 2004. CHC's staff marveled at the creativity and usability of the delivered system. CHC's students were thrilled by the sound and light experience. Especially engaging was the combination of a bubble making machine and projected colors.

7. SOME ISSUES AND BENEFITS

Students who engaged the handicapped population for the first time were sometimes uncomfortable (in the beginning) with the interaction. In our experience, this went away quickly. This represented a growth experience for our students that we had not anticipated. We were extremely pleased with the comfort and acceptance of our students for the clients they were addressing. The issue of quality of life entered the interaction early. Our students realized that their native intelligence and engineering skills could change someone's life by giving clients a technological tool that could compensate for an ability the client lacked. They were allowing the handicapped to converse and to learn choice-making and selection, thereby improving the clients' quality of life. This ability to make a difference was not lost, for the entire length of each project, on the students. Our computer science and computer engineering students indicated that not only did this course provide them with an opportunity to advance their skills and make a contribution to their community, but also it gave them an opportunity to expand their view of the world. One student stated: "It turned on a switch inside".

Managing expectations was paramount. In engaging a target population in need, we built expectations of delivery. Our biggest challenge was not to disappoint David, or the children at the Center, with a failed project. This added motivation beyond a grade in the course for the Computer Science and Engineering students.

Our disabled clients and their caregivers also received unexpected benefits. Delivering the technology certainly acted as a reward. But David, the teachers at CHC and the youngsters there, found themselves educating our students and grew as well.

In the first semester, arrangements were made for David to come to campus. Team representatives met with him and his caregiver to understand the requirements of the augmentative talker he needed. As he patiently pointed to letters and words on a piece of paper taped to his wheelchair tray, our students came to understand not only David's requirements and constraints but David's courage, humor and humanity, all too easily unseen by the outside world because of his disability. As David tested prototype systems, he also became teacher and advisor helping teams adjust systems and coming up with ideas that significantly improved the final product. More important than any of this, David's view of himself and his place in the world changed. As he began to interact with faculty and students David once again saw himself as a productive member of society and he now consults with a number of on-campus research groups on assistive technology.

This experience changed the lives of students as well. Certainly this project makes excellent resume and interview material. But students altered their career paths reflecting the impact of service learning. One woman now works for Microsoft in their user-interface division making systems easier to use. Other students chose to go onto graduate school not just in computer science and engineering or artificial intelligence, but in linguistics and cognitive science as well.

Similar events transpired at CHC. Teachers and therapists knew they made a difference in educating the youngsters in their care. Now they were in a position to educate college students about the handicapped. As they answered questions designed to clarify team requirements and constraints they found themselves clarifying our students' misconceptions about individuals with disabilities. Slowly our student came to understand that disabled youngsters got bored and frustrated with repetitive tasks just as they would. A number of UB students who were academically at risk and who historically were both negative and combative altered their behavior over the course of the project. They immersed themselves in the project moving from isolated individuals to true team players. Their work ethic and the quality of their work improved. And, as they began to see themselves as making a difference both to their teams and their clients they recognized that while they could not control the world around them or the actions of others, how they responded was in their control. Through service learning their worldview was transformed.

Similarly a visit to UB's campus by students from CHC and their teachers became more than a field trip when one 18 year old CHC student was able to respond appropriately socially with a college students despite the confines of her wheelchair and the very limited speech capabilities of CHC's communication device. When she thought an accident might occur between her wheelchair and a technology cart coming down the hallway she managed to get an appropriate warning out to her teacher. No one realized she was capable of this level of understanding prior to her campus visit. And, when our teaching station was delivered everyone understood the benefits and potential the system would provide. Everyone learned and grew. This is what education is all about.

8. SUMMARY AND CONCLUSIONS

Using service learning as a model, but adapting it to the production of new, low-cost technologies we have proposed an innovative approach to computer science and engineering education that improves curricula and raises pedagogical success. Students face a richer set of design opportunities ranging from non-technical client interaction to the complete hardware and software systems design of assistive technologies. They also experience greater motivation because the projects are socially relevant and have the potential to improve the quality of life of a client population. Our client base gains not only new assistive technologies, but also everyone in the client/developer/faculty circle benefits. As Horenstein and Ruane [8] stated:

> "How can we lead our engineering students to see the importance of professional and ethical responsibility, the societal context of engineering, and contemporary issues to their developing professional identity? … A more deliberate plan using the service learning literature, student reflection and writing, and cultural changes in the engineering community on campus, will help increase the social awareness of our own students." [8]

Other institutions that adapt our approach to form relationships with clients in need of technology will be able to formulate an educational experience similar to ours, and achieve positive results for the student and the client.

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