2006-2071: MULTI-CAMPUS COLLABORATIONS AMONG UNDERGRADUATE DESIGN TEAMS: OPPORTUNITIES AND CHALLENGES

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Multi-Campus Collaborations among Undergraduate Design Teams: Opportunities and Challenges

Abstract

There are many benefits to participating in multi-campus collaborations among project-based design teams. First, students gain experience in working in a distributed design environment, which is becoming more commonplace in engineering practice. Second, collaborations offer the ability to share complementary expertise and allow student design teams to participate in projects that they would not normally be able to undertake alone. Third, collaboration among teams of multiple campuses allows for sharing of prior work and the opportunity to build upon the work to have a more significant impact.

There are, however, challenges to participating in multi-campus collaborations. It is difficult for student teams to partition projects such that they can be done somewhat independently. Communication issues can be complicated by distance and the lack of face-to-face contact on a regular basis.

The EPICS - Engineering Projects in Community Service – program engages undergraduate student design teams on long-term projects that solve technology-based problems for local community service organizations. There are sixteen universities with active EPICS programs in the 2005-2006 academic year. While the programs have some variation as EPICS has been integrated into each individual campus, they share basic characteristics. The existence of EPICS programs on multiple campuses has created the opportunity to collaborate across institutions. This paper will describe three models for multi-campus collaboration that have been used in EPICS.

Introduction

The importance of significant design experiences to prepare undergraduate engineering students for engineering careers has been well-documented [1, 2]. These experiences typically emphasize the application of the technical skills as well as the professional skills such as communication, working as a team and customer interaction [3-5]. The need for such experiences has spawned many innovative approaches to senior capstone design courses [6, 7] as well as design courses for underclassmen [8-11]. Most of these courses are confined to one semester or quarter and are intended to give the students an intense exposure to the design process. The model that guided the creation of the Engineering Projects in Community Service (EPICS) curriculum was to involve each student for several semesters or even years on the same long-term project, so that each student would experience varying roles over the course of the project.

EPICS is built around the concept of long-term partnerships between student teams and not-for-profit organizations in the community. Community service agencies face a future in which they must rely to a great extent upon technology for the delivery, coordination, accounting, and improvement of the services they provide. They often possess neither the expertise to use nor the budget to design and acquire a technological solution that is suited to their mission. They thus

need the help of people with strong technical backgrounds. Moreover, the community service agencies will ultimately deploy the teams' systems.

Each team and its community partner work closely together to identify and solve the partner's technology-based problems. Table 1 presents four examples of EPICS teams and projects, selected from the 17 schools that currently have EPICS programs. These illustrate the technical depth, multidisciplinary breadth, and community impact of projects. The projects fall broadly in four areas: education and outreach, access and abilities, human services, and the environment. The sampling of projects also demonstrates the range of ways in which this model has been disseminated and how it takes on different forms in different environments.

The existence of EPICS programs at multiple campuses has brought the possibility to address issues beyond just the local community of a single institution through multi-campus collaborations. Today's designs are often implemented in industry with teams that are not all in the same location. The ability to share information across communities and to add another dimension of a student's preparation for practice through the use of multi-site teams motivated the EPICS program to begin to explore projects that span different campuses. Three models for multi-site collaboration will be discussed.

Curricular Structure of the EPICS Program

A unique curricular structure enables each EPICS team to maintain a long-term relationship with its community partner and to successfully design and deliver products that have significant technical complexity and significant community impact. EPICS is implemented as a track of courses, where a team corresponds to a division or lab section of the course. Each team is large – 8 to 20 students – and vertically integrated – composed of freshmen, sophomores, juniors and seniors. A student may be a member of a team for up to four years, registering for 1 to 2 credits each semester. When seniors graduate each year, returning students move up a year and new students are added to the team. Many EPICS teams have developed formal training processes for new members. The large team size, vertical integration, and credit structure enable each team to continue with a core of returning students each semester and year. In effect, the teams function as a small engineering design firm, with the community partner as its customer. This enables the teams to tackle and complete projects of significant size, complexity and impact in the community. Some teams have been in operation for ten years and have delivered a series of projects to their community partner[12, 13].

From an educational point of view, the long-term continuity enables the students to experience the whole design cycle, from problem definition through support of fielded projects. The EPICS Entrepreneurship Initiative takes this cycle one step further by providing opportunities for students to learn about and pursue the commercialization of their projects. The long-term continuity also enables each student to experience different roles on the team, from trainee to design engineer, to project or team leader.

Complementing the long-term structure of EPICS teams is the multidisciplinary nature of the teams. Started in electrical and computer engineering at Purdue in 1995, EPICS spread rapidly both across engineering and outside engineering, to computer science, sociology, and many other

Table 1. Example EPICS Projects

Education and Outreach:
Location: Purdue University
Community Partner: The Imagination Station is a hands-on science and space museum in Lafayette, Indiana. It offers a variety of interactive displays, many of which were developed by Purdue EPICS teams.

The projects developed with and delivered to Imagination Station have covered a very wide range of disciplines, including electromagnetism, aerodynamics, and hydrology. For example, an interactive wind tunnel was designed and created by a team to provide an opportunity for children in elementary school to learn about aerodynamics. Another project, called the Mag Racer, teaches children about electromagnetism. It consists of a magnetic car inside a tube-shaped track running through a series of electromagnets. Children try different strategies for activating the electromagnets to figure out how to make the car race down the length of the track. Other interactive displays include ones showing the water cycle with sets of LED's; teaching density mixing colored water and oils; and science software housed in a dinosaur-shaped kiosk.

Access and Abilities:
Location: EPICS Program at Bedford-North Lawrence High School, Bedford, Indiana
Community Partner: OLJMG Joint Services, a five-county agency that coordinates special education in the North Lawrence Indiana Community School system

This is the first EPICS program that is not associated with a university. We are proud to say, though, that it was started by three EPICS alums who, after graduation, took jobs near Bedford, Indiana. They worked with their employers, the Crane Division of the Naval Surface Warfare Center and Visteon, and with teachers at the local secondary school to create the first high school EPICS program. The commitment of these alums to continue their service to the community demonstrates the long-term impact that EPICS has on the lives of our students.

The high school students have developed a system consisting of several devices that enable a fellow student with cerebral palsy to sense when she needs to swallow in order to avoid drooling. One device, which measures the time between swallows, is integrated into an inconspicuous necklace that she wears. If the time between swallows does become too long, then another device worn on the wrist or the waist can either vibrate or make noise to remind her to swallow.
This is an innovative device – the students found nothing like it despite diligent patent and product searches. This opened up the opportunity for the team to participate in one of the new aspects of our program: the EPICS Entrepreneurship Initiative. This helps spread the benefits of EPICS products by commercializing those addressing the most significant unmet needs. The potential of products is determined via an annual product feasibility competition called the EPICS Idea-to-Product Competition. The ingenuity of the BNL EPICS team's system won the team a second-place finish in the competition this past April. The team used the funds they won to file a provisional patent on their product.

Environment:
Location: The University of Auckland, New Zealand
Community Partner: The Waiheke Island Waste Resource Trust
The dissemination of the EPICS to other universities made a great leap forward with the addition this past year of the first international EPICS site, at the University of Auckland. Two teams are working with their partner to improve the environment on and the economy of the island. One team is developing a portable glass crushing plant to process waste glass collected on the island into clean sand for use in construction materials. This project is thus turning a waste product that would otherwise have to be shipped off the island into an economic resource. A second team is developing a pilot facility to process waste cooking oils, primarily from restaurants on the island, into bio-diesel. A potential pollutant is thus being turned into an alternative fuel for municipal vehicles.

Human Services:
Locations: Purdue University, University of Notre Dame and the University of Wisconsin-Madison
Community Partner: Habitat for Humanity International

Having EPICS programs at multiple universities has created the opportunity to collaborate on common projects across campuses to address needs of regional, national, or even international scope. A Memorandum of Understanding was signed in 2002 between EPICS and Habitat for Humanity International (HFHI) to develop national-scale projects. The first multi-site project was a database for local HFHI affiliates to use for gathering, storing, and analyzing assessment data of homeowners from across the country. This project was jointly developed by teams from Purdue and Notre Dame and was delivered last year. A second project, a multimedia volunteer training system is being jointly developed by teams at Purdue and Wisconsin-Madison. The staff of HFHI in Americus, GA serves as the community partner. Each site also works with the local affiliate of HFHI to ensure that the products being developed meet their needs and will be used by such affiliates.

disciplines. Each team advertises for the students and disciplines it needs each semester for its project. The multidisciplinary nature of the team adds an important educational dimension and has proven critical to the quality of the products that the teams develop and deliver.

Each student in the EPICS Program attends a weekly two-hour meeting of his/her team in the EPICS laboratory. During this laboratory time the team members will take care of administrative matters, do project planning and tracking, and work on their project. All students also attend a common one-hour lecture each week. A majority of the lectures are by guest experts, and have covered a wide range of topics related to engineering design, communication, and community service. The long-term nature of the program has required some innovation in the lecture series since students may be involved in the program for several semesters. This has been addressed by rotating the lecture topics on a cycle of two to three years and by creating specialized lecture supplements called skill sessions that students can substitute for lectures they have already seen. Example skill session topics include learning to operate a mill or lathe, developing effective surveys, and tutorials on multimedia software. We have found that students use the skills sessions as a way of gaining specific expertise needed for their projects, and also as an opportunity to broaden their experience, for example, a computer engineering student learning to use a lathe or a mechanical engineering student learning web programming.

Multi-campus projects

The existence of EPICS programs at several sites has opened the possibility of addressing community and educational needs that extend beyond those of a university and its local community. Multi-campus projects are appealing from a community service perspective as expertise or products that are developed at one institution could be shared with other communities through sister EPICS programs thereby expanding the impact of the products. It would provide a way for more people to be served.

From an educational perspective, giving students the experience of participating on a team that is comprised of students they can see each day and others who are in a different location simulates the kinds of teaming that they will encounter after graduation. These kinds of experiences have met with a lot of enthusiasm from our industrial partners.

While the multi-campus projects are appealing, there is additional overhead that is required and challenges. Three examples of multi-campus collaborations that are used by the EPICS program with undergraduate student projects are described.

Habitat for Humanity

Several of the agencies that EPICS teams are working with are national in scope, such as Habitat for Humanity. The possibility of EPICS project teams working with agencies in different cities and addressing national-scale problems led to a discussion with the staff of Habitat for Humanity International (HFHI) about becoming the first National EPICS Project Partner. Habitat was particularly appealing as a national partner since there were local affiliates in most of the locations where EPICS programs were operating and the relationship of local affiliates was similar to the relationships of local EPICS programs. In February 2002, a Memorandum of

Understanding between EPICS and HFHI was signed to begin a national partnership. Two EPICS programs piloted the multi-university model: Purdue University and the University of Wisconsin, Madison. Teams from these programs worked with the Habitat for Humanity staff one two projects. One was a set of construction tutorials for national distribution to Habitat volunteers and the other is a data collection infrastructure to allow Habitat to assess its impact on families on a national level. These projects have had the national staff of Habitat for Humanity as the project partner, and they offer the opportunity for students at multiple sites to collaborate on a common project. Each site also works with the local affiliate of Habitat for Humanity to insure the products being developed meet their needs and will be used by such affiliates. A third EPICS program, Notre Dame, joined the collaborative projects in 2004. Student teams from each of these programs have traveled to Habitat's headquarters in Georgia to present their work in 2003 and 2004 and delivered its first completed national projects in April of 2005.

National Survey Data Portal (NDB)

The main objective of the National Survey Data Portal (NDB) is to provide the software infrastructure that will allow Habitat for Humanity International (HFHI) to create and administer surveys on a national level to assess the impact of new homeownership and the programs offered by Habitat on the quality of life of the recipients. The NDB team constructed a web-based solution to HFHI's need of the ability to track standard of living changes among homeowners. The team devised a tool that is separated into 3 categories: Survey Generator (with a built in question/answer generator), Survey Response Collector, and a Statistical Analysis tool. The Survey Generator and Input collector both have been designed and delivered to HFHI in April of 2005. It is currently being adapted to be used across Indiana by the state Habitat for Humanity organization. A post-processing statistical analysis tool is being developed by students at Notre Dame who have been collaborating on the project.

Volunteer Training Tutorials

The purpose of the Volunteer Training Tutorials project is to assist Habitat for Humanity affiliates with the training of volunteers. New volunteers continually come to Habitat's affiliates, typically for a day. Reducing the time and increasing the effectiveness of their training can dramatically improve both the quality of their work and the amount of time they can spend contributing to the home construction. Currently, no common training mechanisms exist across affiliates that have been endorsed by Habitat nationally. Information is provided, but it is not easily used for training and can vary in different parts of the country. The goal of this project is to create the infrastructure for such a common training system and to begin to populate the system with training materials.

The initial prototypes for the training modules were created by a team at Purdue University using an Internet-based multimedia tool. They incorporate text and pictures to instruct users on how to perform basic volunteer construction tasks. Completed tutorials included siding, framing and painting. A set of quick reference sheets for distribution on job sites was included. After review by the national staff and discussions on a broader set of materials, the project was restructured into a multi-campus project. A team at Purdue would focus on developing a user-friendly software tool that would allow non-programmers to create the tutorials and quick reference guides to be used on the job site. The initial tools required programming knowledge and the new tools would allow content experts with minimal programming knowledge create the materials. A

team at the University of Wisconsin-Madison has taken the lead producing the content for the training materials. Working with the local Dane County Habitat Affiliate, they have developed basic training materials. The team at Wisconsin has functioned as the customer for the Purdue software developers along with the staff at HFHI's national office. Prototypes of the new tutorials are under by Habitat and a full set is under development.

The teams have functioned with a combination of phone calls, emails and face to face meetings. The experiences have taught us that an initial face to face meeting is very important to the success of that semester's objectives. The semesters when we have relied solely on virtual communication have suffered. One of the best experiences for building the teams have been trips down to the international headquarters of Habitat in Georgia. Funding these trips is not often easy but fortunately, thanks to a generous gift from Microsoft, we have been able to continue. Initial trips took smaller groups of students and flew down. These were great experience for those who attended. The last two years, we have taken students from all three schools on a bus. While this has been a very long trip, it has done a great deal to help build the connections between teams. A challenge with these trips is that they have been at the end of the year when we have had progress to show the staff at Habitat. Time and financial resources have limited our ability to conduct multiple trips.

Assistive Technology

The work with Habitat for Humanity lent itself to large projects that could be split into pieces that could be developed with input form the local affiliates. Assistive technology projects are being produced on many campuses and offer an opportunity for collaboration but not on large projects. Most of the work in the EPICS programs in assistive devices and access and abilities is done to customize a product for a local user. There is a specific person or group of people who the system is being designed for. Having students from another location who can not see or talk to the person adds challenges that makes it a less desirable multi-campus project. At the same time, there is very similar work going on at each site that the students could collaborate on.

The model for collaboration that has been explored in EPICS is to use the Access Grid[14] to allow teams to share presentations and design ideas. The Access Grid, a network of more than 70 domestic and international sites using high-speed Internet connections to enable interactive meetings among participants. The Purdue Access Grid facility utilizes multiple cameras and screens to allow participants to move around the room and incorporate non-digital materials into their presentations. The Access Grid also supports multimedia display applications, such as PowerPoint, MPEG video, and OpenGL windows. Providing real time video and audio, the Access Grid facility can be useful in supporting large-scale distributed meetings, collaborative work sessions, seminars, lectures, tutorials, and training. On many campuses, the facilities are free to faculty and students for instructional purposes. Collaboration is also possible with institutions without the Access Grid with the use of a webcam and connection to an instruction with the Access Grid capability.

Using the Access Grid, teams from Purdue University and WPI have been able to present their designs to teams at the other universities and discuss ideas for designs. The system allows for multiple universities to be linked together on the same session using the access grid.

Course Management Software

A third collaboration involves the development of customized course management software. The unique curricular structure and long-term teams has required the development of customized software to manage the teams. The Purdue University EPICS Program initiated a team to develop customized solutions to help manage EPICS. As programs have spread across the country, similar needs have arisen. A plan to export the software tools to other sites required the development of a common set of specifications that would allow the tools to be implemented at multiple schools. The approach that was chosen was to initiate teams at multiple schools that could collaborate on a common set of tools.

Initial project planning has been conducted with phone calls, emails and instant messages. Open Source software such as WordPress[15] and MediaWiki[16] has been used to share project documentation between teams. WordPress is an authoring tool that allows users to publish weblogs containing frequently updated commentary. Team members update their personal weblogs to reflect their current commitments and ideas, including links to relevant articles or discussions. MediaWiki is software that allows users to create wikis, which are collaborative websites editable by any user. All information in each team member's personal weblog and the project wiki is searchable by any team member.

Teams from Purdue University, San Jose State University and the University of California-San Diego have used a wiki to organize and store project support documents, meeting minutes and team contact information. Development plans call for the Purdue University team to design a basic system that implements user and team management and allows modules to be added. Teams of students from San Jose State University will design and build modules that extend the functionality of the base system released by the Purdue University team. Access Grid meetings will be held as system components are defined and modules are designed. Source code will be placed in a version control system and will be accessible to all team members.

Conclusions

The multi-site collaborations have a lot of promise from an educational and impact standpoint. They provide an opportunity for students to experience teaming both on the same campus and across remote locations. They interact with customers and team members both locally and remotely, which helps to prepare the students for professional practice. The benefit to the community is that locally designed projects have impact beyond the local communities. Specific examples of the positive results include the delivered project to HFHI national and the continued collaboration between universities. Our experience has taught us that more infrastructure is required by projects that are distributed across multiple campuses, and that more overhead is required for the projects. Whenever possible, it is best for the multi-campus teams to have face to face meetings early in the collaboration. In addition, we have found that the ability to share designs across teams via databases and software is needed.

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