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EPICS: Engineering Projects in Community Service*

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Engineering Projects in Community Service, EPICS, is an engineering design program that operates in a service-learning context. EPICS students earn academic credit for their participation in design teams that solve technology-based problems for not-for-profit organizations in the local community. The teams are: multidisciplinary—drawing students from across engineering and around the university; vertically-integrated—maintaining a mix of freshman through seniors each semester; and long-term—each student participates in a project for up to seven semesters. The continuity, technical depth, and disciplinary breadth of these teams enable delivery of projects of significant benefit to the community.

THE EDUCATIONAL NEED

UNDERGRADUATE STUDENTS in engineering face a future in which they will need more than just a solid technical background to be successful. In setting the goals for any system they are asked to design, they will be expected to interact effectively with people of widely varying social and educational backgrounds. They will then be expected to work with people from many different disciplines to achieve these goals. They thus need educational experiences that help them develop these skills.

Among the most dramatic statements about the importance of these skills are the set of desired educational outcomes that form the heart of the engineering accreditation guidelines, dubbed 'Engineering Criteria 2000', that went into effect in the United States in 2000 [1]. In addition to knowledge of engineering, mathematics, and science, and experience in engineering problem solving and system design, these criteria call for students to be able to function on multidisciplinary teams and to communicate effectively. They also call for students to understand a wide range of issues, including the importance of professional and ethical responsibility and the societal and global impacts of engineering solutions.

One effective response to these calls for reform is a curriculum that engages students in 'real-world' experiences [2–8]. The design of these experiences is crucial; they must offer students a compelling context for engineering design, a multi-disciplinary team experience, sufficient time to learn and practice professional skills, personalized mentoring, and exciting technical challenges. The combination of these five characteristics ensures that students will immerse themselves in the engineering experience, thus learning the desired skills and addressing the desired issues as they perform their tasks.

THE COMMUNITY NEED

While educators seek to provide learning environments that prepare students for life as engineering professionals, not-for-profit organizations—such as community service agencies, schools, museums, and local government offices—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 to the community. They often possess neither the expertise nor the budget to acquire or design a technological solution that is suited to their mission. They thus need the help of people with strong technical backgrounds.

The responses to this need for technology in the not-for-profit sector have taken many forms. At the federal level in the USA, the National Institute on Disability and Rehabilitation Research (NIDRR) provides leadership and support for a comprehensive program of research related to the rehabilitation of individuals with disabilities. NIDRR sponsors ABLEDATA, a federally funded project whose primary mission is to provide information on assistive technology and rehabilitation equipment available from domestic and international sources to consumers, organizations, professionals, and caregivers within the United States.

At the state level in the USA, there are many forums for the exchange of ideas and processes for improving social services with technology. For example, the 2003 Conference on Information Technology Strategies for Social Services offers many insights into ways that social services can utilize technology to improve their effectiveness and efficiency. The Journal of Technology in Human Services explores the uses and potentials

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of computer and related technologies in mental health, developmental disabilities, welfare, and other human services.

The existence of these information resources does not, by itself, guarantee that they will benefit every agency or individual that needs them. Again, there is a need for people with strong technical backgrounds that can work closely with not-for-profit organizations to advise them on the use of technology. Such people are absolutely essential when special needs call for new technology to be developed or for existing technology to be modified.

EPICS: COMBINING ENGINEERING EDUCATION AND SERVICE TO THE COMMUNITY

The Engineering Projects in Community Service (EPICS) Program was initiated at Purdue in 1995 to fulfill the complementary needs of engineering undergraduates and the community [9]. Under this program, undergraduates earn academic credit for their contributions to long-term, team-based design projects that deliver innovative, technology-based solutions to problems identified by not-for-profit organizations in the community. The unique structure and operation of EPICS enables solutions of significant benefit to the community to be delivered. Key features of the EPICS model include the following attributes. While one or sometimes several of these attributes of EPICS can be found in other design programs, EPICS is unique in combining all of them.

Community partners

Each EPICS team is matched with a not-for-profit organization in the community that is referred to as the 'project partner.' The team and its project partner work closely together to identify and solve the project partner's technology-based problems. The end result is the delivery and support of a system that is used by the project partner to improve the services they provide to the community. The partner's suggestion of project ideas and constant feedback on the efficacy of the systems being developed and deployed provides the 'real-world' context for each EPICS project. An EPICS team's delivery—in most cases, at no cost—of systems that the project partner requests, provides the 'real-world' assistance that the partner needs to better serve the community. The very beneficial effects that these systems have on the community provide a compelling reason for students to join and pursue these projects.

Large, vertically-integrated teams

Each EPICS team consists of eight to twenty students, thus enabling projects of significant scale and potential impact on the community to be undertaken. The large team size also enables them to be vertically-integrated; that is, to include freshmen, sophomores, juniors and seniors. In general, the seniors provide technical and organizational leadership, the sophomores and juniors perform the technical work organized by the seniors, and the freshman learn about the project partner's needs and participate in teams tasks as possible.

Long-term student participation

An EPICS student can participate in an EPICS team for up to seven semesters, joining a team in the second semester of the freshman year, remaining with the team until graduation. New freshmen or sophomores replace students that graduate or otherwise leave the team. There is thus significant continuity in team membership from semester to semester and year to year. When this continuity in membership is combined with team procedures for the training of new students and with mentoring by senior members and team advisors, the team's effectiveness can be maintained for as long as required to complete a large-scale project. This continuity also provides each student with the time and mentoring opportunities required to learn and practice different roles on the team, from trainee to design engineer to team leader.

Variable credit hours

An EPICS student earns one credit per semester as a freshman or sophomore. As juniors or seniors, they earn 1 or 2 credits per semester, with the choice being made by the student each semester. The doubling of credits available to juniors and seniors parallels their growing technical capabilities and organizational responsibilities. How the academic credit counts towards a student's graduation requirements varies by department. For example, in ECE, up to 6 credits may be used as ECE elective credit, and 3 credits in the senior year may be used to fulfill the capstone design requirement. ME students may use up to 6 credits to fulfill a technical elective requirement.

Multidisciplinary teams

The large team size also enables students from disciplines across engineering and around the university to participate in an EPICS team. The disciplinary composition of an EPICS team can thus be tuned to a project's needs. For example, teams producing devices to assist children or adults with disabilities have drawn from such disciplines as electrical engineering, mechanical engineering, computer science, child development and nursing.

Start-to-finish design experience

EPICS provides a start-to-finish design experience for students. Each project begins with identification of the project partner's needs and the definition of a project to meet one of more of those needs. It then progresses through design, development, testing and deployment with the project partner. This process typically takes two or more years, thus providing the students with sufficient time to master the many different aspects of an engineering design project, including: exploration of design alternatives, project planning and management, team leadership, technical innovation, design revisions, and economic considerations.

EPICS AND SERVICE LEARNING

Service learning combines service to the community with student learning in a way that benefits both the student and the community. According to the US National and Community Service Trust Act of 1993 (as amended through December 17, 1999, P.L. 106–170):

Title I—National and Community Service State Grants Program
Subtitle A—General Provisions
Section 101 [42 U.S. C. 12511] Definitions:
(23) SERVICE LEARNING:

The term 'service-learning' means a method:

(A) under which students or participants learn and develop through active participation in thoughtfully organized service that (i) is conducted in and meets the needs of a community; (ii) is coordinated with an elementary school, secondary school, institution of higher education, or community service program, and with the community; and (iii) helps foster civic responsibility; and
(B) that (i) is integrated into and enhances the academic curriculum of the students, or the educational components of the community service program in which the participants are enrolled; and (ii) provides structured time for the students or participants to reflect on the service experience.

A summary of the legislative history of national and community service in the United States can be found at http://www.nationalservice.org/about/lhistory.html

The benefits of integrating service learning into an engineering curriculum have been documented in several recent papers, including [10]. Recent examples of engineering service learning programs include projects integrated into freshman-level introductory courses [11, 12], capstone senior design courses [12, 13], and multidisciplinary approaches [14]. Other initiatives have sought to integrate the co-curricular activities of student organizations with engineering service learning [15].

The EPICS program embeds engineering design in a service-learning context [16]. This interweaving of design- and service-learning into an ambitious multidisciplinary, vertically-integrated course structure with an emphasis on long-term community partnerships and long-term engineering projects is unique to the EPICS program.

The service context for each EPICS design project provides a very compelling framework for the students. Metacognitive activities are woven into each semester to allow students to understand the connections between their technical projects and the community issues they are helping to address [17]. EPICS students thus learn many valuable lessons in citizenship, including the role of community service in our society; the significant impact that their engineering skills can have on their community; and that assisting others leads to their own substantial growth as individuals, as engineers, and as citizens.

EPICS: A CONCISE HISTORY AND OPERATIONAL DETAILS

EPICS was initiated in the School of Electrical and Computer Engineering at Purdue University in Fall 1995, with 40 students participating on five project teams. The program has grown steadily in both size and breadth. In the 2002–03 academic year, over 400 students participated on 24 teams, addressing problems ranging from data management for social services to mitigation of agricultural pollution and from designing learning centers for local museums to developing custom play environments for children with disabilities. EPICS spans all engineering disciplines at Purdue and includes students from over 20 university departments.

Each EPICS project involves a team of eight to twenty undergraduates, a not-for-profit community partner—for example, a community service agency, a museum or school, or a government agency and a faculty or industry advisor. A pool of graduate teaching assistants from seven departments provides technical guidance and administrative assistance.

Each EPICS team is vertically-integrated, consisting of a mix of freshmen, sophomores, juniors, and seniors and operates for several years, from initial project definition through final deployment. Once the initial project(s) is/are completed and deployed, new projects are identified by the team and its project partner, thus allowing the team to continue to work with the same community partner for many years. Each undergraduate student may earn academic credit for several semesters, registering for the course for 1 or 2 credits each semester. The credit structure is designed to encourage long-term participation, and allows multi-year projects of significant scope and impact to be undertaken by the teams.

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 address administrative matters, do project tracking and planning, and work on the technical aspects of 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 because 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, conducting patent searches, and tutorials on multimedia software. Students use the skill sessions as a way of gaining specific expertise needed for their projects and 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.

PHASES OF EPICS PROJECTS

The curricular structure of EPICS enables long-term projects. Over time, each project has five phases: establishing project partners, assembling a project team, developing a project proposal, system design and development, and system deployment and support.

Phase 1: Establishing project partnerships

The university-community partnership is at the heart of any service-learning program. In the context of EPICS, this entails exploring the technology needs and aspirations of local not-for-profit organizations.

When planning for the EPICS program started in 1994, we were able to contact many different service agencies by making a presentation about the envisioned program and its goals to the directors of all local United Way agencies. Information about United Way of Greater Lafayette, the organization that hosted the meeting at which the concept of EPICS was presented to the director's of many agencies, can be found at: http://www.uw.lafayette.in.us/. In other countries, a different approach to identifying and contacting potential project partners may be needed.

This single presentation led to many discussions with individual agencies and a long list of potential projects. The selection of community partners, designated *Project Partners*, from this first set of agencies was based on four key criteria:

1. *Significance*—not all projects can be undertaken, so partners whose projects should provide the greatest benefit to the community are selected.
2. *Level of technology*—projects must be challenging to, but within the capabilities of, undergraduates in engineering.
3. *Expected duration*—projects that will span several semesters offer the greatest opportunity to provide extensive design experience on the academic side and to address problems of potentially high impact on the community side. It has also proven valuable to achieve a mix of short- (one semester to one year) and long-term (multi-year) projects, in that the short-term projects build confidence and help establish the relationship between the student team and the community partner.
4. *Project partner commitment*—a crucial element of the program has been the commitment of individuals in the partner organizations to work with the students to identify projects, specify requirements, and provide ongoing critical feedback.

Each year, EPICS has added new teams using the significance, level of technology, expected duration, and project partner commitment criteria. Since the first round of projects that grew out of the United Way presentation, the source of new projects has been varied. Faculty have initiated some projects; students have suggested others. As the program has become known in the community, several projects have been proposed by local community organizations. From five initial teams in Fall 1995, the program has grown to 24 teams, as summarized in Table 1.

Phase 2: Assembling a project team

Once a project and project partner have been identified, a student team is organized. This is done through discussions with and mailings to academic counselors, by advertising the projects each semester in an evening callout and in undergraduate classes, and via on-line registration at Purdue's EPICS website: http://epics.ecn.purdue.edu/. Eight to twenty students are chosen for each project team, with the assignment of students managed by the EPICS Student Advisory Council, on which each team has a representative.

Depending on the project's needs, a team may select students from multiple engineering disciplines and many non-engineering disciplines. Over 20 academic majors have been involved in the program, including electrical, computer, mechanical, civil, aeronautical, biomedical, and industrial engineering, computer science, sociology, psychology, education, audiology, English, nursing, visual design, forestry and natural resources, chemistry and management.

Vertical integration—a mix of freshmen, sophomores, juniors, and seniors—is also a factor in team assignments. Teams need both technically advanced members (typically juniors and seniors) to spearhead technical progress and (academically) younger members who are learning about the project and will carry it into future semesters. The combination of a vertically-integrated team and long-term student participation ensures continuity in projects from semester to semester and year to year. Projects can thus last many years as new students are recruited for the project to replace graduating seniors.

Table 1. The 24 EPICS teams active at Purdue during the 2003–04 academic year

Community partner	Year initiated	Tasks	Disciplines
Wabash Center Children's Services	1995; 2nd team added in 1996	Develop computer-controlled toys for children with physical disabilities. Develop an artificial sensory environment to provide multi-sensory stimulation and a sense of control to children with physical disabilities. Provide ways for physically disabled children to control their motion and to play with peers.	CmpE, EE, MatE, ME, CS, Nursing, Child Development
M.D. Steer Speech-Language and Audiology Center	1995	Automate calculation of speech rate for clinical sessions. Design specialized speech recognition systems. Design directional microphone system for hearing aids.	EE, CmpE, CS, Audiology and Speech
Lafayette Crisis Center	1995	Design stand-alone kiosks that will provide information about community services to people in need of assistance. Incorporate means of contacting appropriate agencies.	EE, ME, CmpE, IE, CS, Liberal Arts
Greater Lafayette Affiliate of Habitat for Humanity	1996	Design systems, structures, and floor plans to minimize home construction and energy costs. Investigate new construction techniques and materials. Design data management systems for local, regional and national operations.	Civil-E, EE, ME, CmpE, IE, Mgmt, CS
Happy Hollow Elementary School	1997	Develop technology-based interfaces to improve the usability of school science, computing, and media facilities, including a weather station and a TV studio. Develop an interactive science center in the school.	EE, ME, CmpE, CS, Education
Klondike Elementary School	1997	Design custom educational software, multimedia and interactive tools for use in the school. Develop technology-based solutions to school infrastructure problems.	CmpE, EE, ME, Education, Liberal Arts
Imagination Station (local, interactive science and space museum)	1997, 2nd team added in 1999	Develop hands-on exhibits that demonstrate science and engineering principles for the Imagination Station Interactive Science and Space Museum.	EE, IE, ME, CmpE, CS, CE, ChmE, Liberal Arts, Education
Purdue's Office of the Dean of Students Adaptive Programs	1997	Design classroom furniture for physically handicapped college students; develop closed-captioning systems for deaf and hard-of-hearing college students.	EE, ME, CS, CmpE, Liberal Arts
Tippecanoe County Historical Association	1997	Develop multimedia and electromechanical systems for on-line storage and interactive presentation of historical information.	EE, CmpE, ME, CS, Education, Liberal Arts, History
Lafayette Adult Resource Academy	1998	Develop computer hardware and software to help non-native English speaking adults become acquainted with the community and gain job-related English skills; develop a uniform computer interface to allow LARA staff to use a wide range of computer programs with their clients; develop software to facilitate record-keeping and reporting.	EE, ME, CmpE, CS, Liberal Arts, Education
Wabash Center Greenbush Industries	1998	Develop aids to assist workers with disabilities as they perform simple manufacturing tasks.	EE, ME, IE, CmpE
Purdue Department of Forestry and Natural Resources	1998	Develop and construct a test constructed-wetlands area to mitigate agricultural runoff from cattle, dairy, and swine farms and to treat creek water. Develop educational infrastructure to make the constructed wetlands an environmental education center for the community.	CE, EE, ME, Environmental Engr, Chem, Bio, Natural Resources, Agriculture, Forestry
Lafayette Columbian Park Zoo	1999	Design a multimedia learning center, including exhibits, kiosks, interactive computer programs, and sound systems for the zoo.	CmpE, CS, EE, Civil-E, ME, Visual Design, Education
The Anita Borg Institute for Women and Technology	1999	Develop information technologies, and tools based on the perspective, and needs of women, with focus on home, family and community.	EE, CmpE, CS, Comm, ChemE, Liberal Arts
Tippecanoe County Probation Department	2000	Develop a database system to assist the Tippecanoe County Probation Department in pre-sentence investigations and supervision of clients.	CS, CmpE, Sociology
EPICS Administration	2000	Design multi-function, distributed information systems to help EPICS teams and the EPICS administration document and manage program and project activities and share information, experience, and expertise.	CS, CmpE, Mgmt
Purdue School of Education's Dean's Office	2000	Develop effective models for using new computation and communication technologies in pre-college classrooms and collaborative learning environments. Design networks of specialized tools to facilitate group learning and problem solving focused on 'real life' situations or simulations.	CS, CmpE, EE, ME, Liberal Arts
Indiana Association of Soil and Water Conservation Districts	2001	Work with local community organizations and industries to improve the Elliot Ditch eco-system which runs adjacent to local industries and through residential neighborhoods.	CE, EnvirE, AgBioE, English, Natural Resources, Forestry
Tippecanoe County Purdue Cooperative Extension Service	2001	Develop information distribution systems to enable the Purdue Cooperative Extension Services to serve its constituents more effectively.	CmpE, CS, EE, ME, Agriculture, Liberal Arts
Art Museum of Greater Lafayette	2002	Design and develop an environmental monitoring system for the museum to better preserve their collections. Design and develop interactive activities for patrons of the museum. Create an attractive environment for the museum while implementing outreach and educational programs.	Art and Design, Building Construction Management, Computer Graphics Technology, EE, IE, ME, Art Education, Art History
Lafayette School Corporation	2002	Develop outdoor science laboratory for high school with particular attention to issues in biology and environmental engineering. Develop and manufacture equipment to assist children with physical disabilities.	ME, CS, CmpE, Math, Edu, EE, Eng Edu, Earth & Atmospheric Sciences
Greater Lafayette Volunteer Bureau	2003	Develop software applications that assist the bureau in its mission of matching volunteers with social service agencies.	CmpE, CS, IDE, Liberal Arts
LEGO Scanning Probe Microscope	2003	Utilizing LEGOs and Mindstorm products, develop a larger than life, LEGO-based scanning probe microscope to illustrate the basic principles behind this instrument that has proved to be a pivotal tool in the emergence of nanotechnology. Develop a design appropriate for a permanent museum display and a portable design for K-12 classroom demonstration.	CmpE, EE, ME, Computer Graphics Technology, Physics, Visual Design
West Lafayette Public Library	2003	Develop software support for the library's new facility, including and extensible and dynamically generated web presence, reliable and secure wireless and wired networks, printing systems, and a multi-platform music repository.	CS, ECE, EE, Computer Graphics Technology, Technical Writing

Phase 3: The project proposal

During the first semester of a project, the project team meets several times with its project partner and the team's EPICS advisor to define the project and determine its goals. During this phase, the project team learns about the mission, needs, and priorities of the project partner. A key aspect of this phase is identifying projects that satisfy three criteria: they are needed by the project partner, they require engineering design, and they are a reasonable match to the team's capabilities. This process of project definition culminates in a written proposal and presentation. The proposal must be approved by the EPICS advisor and accepted by the project partner.

Phase 4: System design and development

Following acceptance of the proposal, the project team's goal is to produce a prototype of the proposed system or service. Regular interaction with the project partner continues in order to ensure that the products being designed and developed are as desired. The formal portion of this interaction includes written progress reports, periodic design reviews, and presentations. A faculty advisor and graduate TA meet weekly with the team to provide technical supervision. This phase of a project lasts as many semesters as necessary for the team to complete the project to the satisfaction of the project partner.

Phase 5: System deployment and support

The ultimate goal of each project team is to deliver a product or service to their project partner. The team must train representatives of the partner, collect feedback, and make any reasonable changes requested by the partner. One of the hallmarks of the EPICS program is that the systems designed and built by the students are deployed in the field, where they provide real, needed benefits to the community. It has been our experience that after a team fields a project, the team and project partner work together to develop new project ideas in order to continue the relationship. The students on the team in future semesters assume responsibility for supporting and maintaining the fielded projects. This structure not only provides the local community with useful projects, but also provides long-term technical support resources for the local agencies and organizations.

EVALUATIONS OF THE EPICS PROGRAM

Student evaluations

Student evaluations of the program have included quantitative evaluation along the specific educational objectives, as well as descriptive formative and summative evaluations. A majority of the students polled have cited the opportunity to obtain 'practical, real-world experience in engineering design' as their primary reason for participating in the EPICS program. A significant number have also identified the opportunity to do community service as a major factor in their participation. Many of the students report that they have done community service in the past, in activities such as tutoring, church work, scouting, soup kitchens, crisis hotlines and volunteer work for Habitat for Humanity. They have not, however, reported prior experiences that combine community service with engineering.

Since the start of EPICS, we have tracked the retention of students in the program: the rate at which students who are able to return to EPICS (i.e., have not graduated or are not off campus on a cooperative industry assignment) do so. The overall retention rate from one semester to the next has been over 77%.

Quantitative evaluation has focused on specific course/program objectives. Table 2 shows the percentage of students rating the course with an A or B grade for each objective, accumulated over 15 semesters starting in Spring 1996. *Ability to work on a team* consistently receives the highest grades, followed by *Communication skills* and *awareness of the customer in an engineering project*.

As part of the summative evaluations, students were asked: '*What impact, if any, has the EPICS program had on your resolve to continue in engineering?*' Over the seven semesters that this data was collected, 70% of the students responded that their participation in the EPICS program positively impacted their resolve to continue in engineering. Among the 30% who did not respond positively, several indicated that they were already committed to engineering before and remained so after their EPICS experience, such as graduating seniors.

Qualitative data collected as part of the summative evaluation included students' responses to the question, '*What are the three most valuable things you have learned as a participant of the EPICS program?*' As can be seen in Table 3, 'teamwork' is the most common response to this question; it is selected by an average of 86% of the students each semester. The students also frequently report learning other professional skills that are part of the ABET criteria, including 'communication skills' and 'project planning'. This is noteworthy because it is difficult to teach these skills in traditional classes. 'Leadership' is also selected frequently—approximately one third of the EPICS students eventually assume leadership roles on their teams.

It is interesting to compare these scores with those who listed and did not list technical skills. It has been our experience that the students under-report improvements in their technical skills because of the experiential learning environment. In focus groups, students who did not identify improvement in technical skills could articulate significant development in technical areas. They did not, however, attribute these to the EPICS experience because they felt that they had learned the new material themselves or 'on their own' rather than being 'taught' the material. Because

Table 2. Percent of students responding with a grade of A or B to the question: 'Evaluate the impact that EPICS has had for you on your. . .' A total of 2835 responses were accumulated over 15 semesters: Spring 1996 through Spring 2003.

Attribute	Average for Spring 1996–Spring 2003
Technical skills	71%
Understanding of the design process	80%
Communication skills	83%
Ability to work on a team	88%
Resourcefulness	79%
Organizational skills	77%
Awareness of the community	73%
Awareness of the customer in an engineering project	81%
Awareness of ethical issues	68%
OVERALL EVALUATION	84%

no one lectured or tested them on a technical topic that they learned on their own or as a group, they did not attribute the learning experience to the EPICS program.

Summative written responses of the students' experience include free response questions. Representative comments include:

- *EPICS completely changed my opinion of engineering.*
- *Working on this project has helped me guide the rest of my course work and ideas for a future profession.*
- *Other engineering courses only directly benefit me. EPICS benefits everyone involved.*
- *I have learned that engineering includes more than theory, it includes teamwork, communication, organization and leadership.*
- *It made me understand how every aspect of engineering (design, implementation, team work, documentation) come together.*
- *No longer is engineering just a bunch of equations, now I see it as a means to help mankind.*
- *Opened my heart.*

No formal evaluation has yet focused on the experiences of the women students in EPICS. However, with its focus on engineering in context and strong emphasis on teamwork, communication and commitment, it appears that EPICS is serving as an effective vehicle for encouraging women in engineering and computer science. Over a five-year window, enrollment of women in ECE and ME at Purdue ranged from 10% to 12%, while 20% of ECE and ME students in EPICS were women. In Spring 2001, 33% of the CS students in EPICS were women, compared to 11.5% of the undergraduates in CS. In the first 3 years of the program, during which 20% of the students in EPICS were women, approximately 30% of the team leaders were women.

We hypothesize that broadening the notion of an engineer's core competencies to include the broad spectrum of skills associated with authentic design may contribute to achieving a population of engineering professionals that is gender- and ethnically-diverse [18, 19]. Approaches that have been cited in the literature as positive steps toward encouraging women to stay in science and engineering include framing science in its social context; stressing general educational goals, including communication, in engineering education; employing cooperative, interdisciplinary approaches; and undertaking problems with a holistic, global scope [20–22]. Matyas and Malcolm [23] and Oakes, Gamoran and Page [24] suggest that many of the same factors are relevant for attracting and retaining minorities.

Alumni evaluations

Formal evaluations of the alumni perspective have not yet been done; however, there is significant evidence that alumni highly value their

Table 3. Student responses to the question: *What are the three most valuable things you have learned from being a part of the EPICS program?*

Categories of responses (with representative variations of comments)	Total number of student responses
Teamwork (teamwork, working with others, cooperation, accountability)	1751
Leadership (leadership, responsibility, motivating self and others, taking initiative)	534
Communication (communication skills, presentation skills, public speaking, report writing, communicating with clients)	1008
Organization and Planning (organization, project planning, time management, meeting deadlines and timelines, goal setting)	793
Technical Skills (technical expertise, programming, design process, testing, technical procedures)	754
Real World Experience (real applications, realistic view of working world, experience for real life)	222
Customer Awareness (customer needs, customer support)	174
Community Awareness (community needs, contribution to the community, value of service)	155
Total Number of Respondents	2044

experiences in EPICS. The most concrete examples are the following efforts to support or expand EPICS that have been initiated by EPICS alumni:

Four EPICS teams currently have corporate sponsorships that were initiated within those corporations by EPICS alumni.

Creation of the first High School EPICS program by EPICS alumni from the Crane Division of the Naval Surface Warfare Center and Visteon. These alumni initiated and have been advising an EPICS team at Bedford-North Lawrence High School in Bedford, IN since 2003.

Creation of a scholarship for Civil Engineering students involved in EPICS. This effort was initiated and funded by EPICS alumni.

An EPICS alumnus who won the ECE Alumni Design Award cited EPICS as the course having the most influence on his development as a design engineer.

Community partner evaluations

Community partners provide a valuable means of assessing the success of the EPICS program. A key measure of community satisfaction has been the retention of project partners. In the eight years since the start of EPICS, teams have worked with a total of 28 different project partners (some partners, such as the Homelessness Prevention Network, include several organizations). Twenty-four of these partnerships are still in place. Over half of the teams have completed their original projects; in all but one instance, the community partner has presented the team with new project ideas in order to continue the relationship. Four partnerships have been terminated. One agency to which three software projects had been delivered reported that its needs had been met. One agency was able to identify funds to purchase a commercial product similar to the one being developed by the team, and deemed this a quicker path to having a system in place. A third partnership terminated when the agency filed for bankruptcy protection and a fourth project terminated when the project was turned over to the city Parks Department.

The high level of satisfaction of the project partners is also reflected in surveys of the project partners. In the 2000–01 academic year, 100% of the project partners indicated they were satisfied or very satisfied with their experience with the EPICS program. In 2001–02, 95% reported being very satisfied or satisfied and 5% had a neutral experience. EPICS has received four awards from the community: the 2003 Indiana Governor's Award for Outstanding Volunteerism, a certificate of Outstanding Achievement from the Wabash Center in 1998, and recognition in the 2000 and 2001 West Lafayette Community Honor Roll.

A final indicator of the success of the EPICS program is the more than 150 projects delivered to the local community. Table 4 provides a partial list of these completed projects.

THE NATIONAL EPICS PROGRAM

The EPICS Program was created at Purdue University in the Fall of 1995. Its new model for large-scale engineering design projects in a community context has since spread very quickly. By 1997, EPICS programs were also underway at the University of Notre Dame and Iowa State University. The National EPICS Program was created in 1999. The universities currently participating in this program are Purdue, Notre Dame, Iowa State, the University of Wisconsin-Madison, Georgia Tech, Case Western Reserve, Penn State, Butler, the University of Illinois at Urbana-Champaign, the University of Puerto Rico-Mayaguez, Columbia, the University of California at San Diego, San Jose State University, Worcester Polytechnic Institute and the University of California at Merced.

The existence of EPICS programs at several sites opened the possibility of addressing community and educational needs that extend beyond those of a university and its local community.

The first multi-site EPICS project, the Homelessness Prevention Network project, was initiated in 1997 when the newly formed HPN team at Notre Dame began working not only with agencies in its home city of South Bend, Indiana, but with the Purdue HPN EPICS team as well. The local goal for each team was to enable its partner agencies to share demographic and services-provided information about their clients. The agencies could then produce duplicate-free counts of homeless individuals and families, meaningful data on the use and effectiveness of services, and a record for each client that can be used for case-management across all agencies and all available services. The common goal of these two HPN teams was the sharing of data on homelessness between Lafayette and South Bend.

The second multi-site EPICS project was initiated in 2002 with the Habitat for Humanity. The Purdue, Wisconsin and Notre Dame EPICS teams are working with the staff of Habitat for Humanity International to produce a set of construction tutorials for national distribution and a database for affiliates to use for assessment data of homeowners from across the country. The national staff of Habitat for Humanity serve as the project partner and offer the opportunity for students at multiple sites to collaborate on common projects. Each site also works with the local affiliate of Habitat for Humanity to ensure that the products being developed meet their needs and will be used by such affiliates.

The National EPICS program provides the infrastructure to support the growing number of EPICS programs nationally and, eventually, internationally. Annual conferences have provided a forum for faculty to come together and share the results and best practices of their programs and to learn from others. Web tools being developed to support the directors and faculty involved in these

Table 4. Selected projects delivered to the local community by EPICS teams at Purdue

Project partner	Selected delivered projects
Wabash Center Children's Services	Dollhouse kitchen, bath, and bedroom with electronically controlled refrigerator door, lights, swimming duck, lighted mirror, and sounds. Track-based dump truck with large-format, four-button wireless control. Custom cap and RF controller to monitor posture and to control toys and software. Spaceship structure in which a child in a wheelchair may play computer games at the control console. A four-button phone adapted for children with disabilities. Modifications to commercially available electric car to allow safe use indoors and provide back support for children with disabilities. Modified toy record player with easy-to-use handle. Custom multimedia software for playgroup activities and interactive software for American Sign Language. Internet access, custom web page, and tutorials on computer use for the clinic. Toy switch that is activated by an isolated finger to develop fine motor skills. Internet access, custom web page, and tutorials on computer use.
Purdue Dean of Engineering and Local K-12 Schools	Fourth grade curriculum modules on demonstrating Mechanical, Chemical, Materials and Electrical Engineering. Eighth grade curriculum modules demonstrating Food Processing, Mechanical, Chemical, Materials, and Civil Engineering. Digital Audio Systems display demonstrating CD and MP3 technology. Portable digital-signal-processing-based voice transformation demonstrator.
Purdue Dept. of Forestry & Natural Res.	Design of four-cell constructed wetland, selected and installed wetland plants into the wetland, pumping system from feed stream, weir boxes for flow monitoring system, storage facility, instrumentation, observation platform and educational material.
Habitat for Humanity	New design for house corners to minimize air leakage; thermal imaging of Habitat homes to determine efficiency of Habitat construction techniques; pressure door to detect areas of heat loss. Standardization of Habitat house designs, Web-based home selection guide, energy analyses for design variations, database to manage inventory for Habitat resale store.
Happy Hollow Elementary School	Web page software, electrical design for TV studio. Instrumentation that feeds weather station data to a web page. Water garden display for a rainforest exhibit.Science museum exhibits: 'Life-size camera': A flash wall that uses strobe lights, a dark room, and phosphorous sheets to capture a student's shadow cast on a phosphorescent wall. 'Color wall' demonstrates principles of colored light. 'Memory basketball:' Score-keeping electronics added to an electronic basketball game to compare hits and misses for shots taken with and without vision distorting goggles. Tornado: Project that simulates a miniature tornado in a Plexiglas box. Theramin, laser harp.
Homelessness Prevention Network	Six client machines deployed with local agencies; server deployed and running. Version 5.0 of the software included security and encryption features, full report generation capability, duplicate client-file merge algorithm on server, and custom, private email system to enhance interagency communications. In 2001, the county, in conjunction with the EPICS team, was awarded a Federal HUD grant to participate in a study of homelessness, because the county was one of only 19 in the US that had a homelessness management information system that met their qualifications. Prototype system also deployed for evaluation purposes to Anderson, Indiana.
Imagination Station (Children's Museum)	'History of the PC' exhibit with working hardware/software; bicycle-driven generator to demonstrate principles of gears and power electromagnetism displays—magnetic tower and Magnet Racer, interactive science software installed in a dinosaur-shaped kiosk, interactive windtunnel, interactive mixer display to illustrate density of fluids using oil and water mixtures.
Institute for Women and Technology	Software games: Genie Lamp, M.A.S.H., Balloon-Blast, periodic table, math match numbers game, U.S. state capitals, Great American Women. Educational website and an online environment for the girls. Technology workshops for middle school girls. Prototype design of a 'female friendly' collaborative software lab for Purdue's CS Dept.
Tippecanoe County Probation Department	A database to track vital information for all adults that are on probation with the country's probation department. The database has an MS Access front end and a SQL server backend. The database is in use at 25 different 'client' computers, and will update/modify as changes are made. A prototype that that will track both juvenile and adult offender. A web-based software prototype called 'JDS2Go.'
Lafayette Adult Resource Academy	An interactive English/Spanish guide to landmarks in the community. Prototype tutorial devices of a camera and ruler that integrate the physical system with a computer of vocabulary building and training. A custom desktop interface to simplify computer use for LARA staff. Driving simulator and tutorial, cash register project to teach how to add and subtract money. Budget management travel game to teach budgeting skills. Language and spelling tutorials to prepare learners for the Test for Basic Adult Education, including database-driven pre- and post-tests.
Lafayette Crisis Center	Community information kiosks delivered to local homeless facility and public library. Kiosks provide information about community service providers through a database touch screen monitor. Calls to the service providers can be made using a modem and handset in the kiosks.
LEGO Scanning Probe Microscope	A large-scale working model of a key nanotechnology instrument that generates images of material at atomic dimensions, built from LEGO® for museum exhibits and K-12 outreach.
Purdue's Office of the Dean of Students	Remote classroom captioning using Microsoft NetMeeting, and a system of wireless microphones so a court reporter can hear the lecture from their home and relay that information back to the student. Classroom furniture: adjustable chair for students with chronic back problems; adjustable table for students in wheelchairs. 75 chairs and 25 tables are placed in classrooms around campus as needed by Purdue students.
Speech-Language and Audiology Center	Infrared-controlled lock installed on a locker at a local school to allow a physically disabled student to unlock her locker. Realistic tracheal model to help laryngectomy patients learn how to install in-dwelling prosthesis. Voice-activated children's software to motivate speech in developmentally delayed children. Software for computing speech rate of spontaneous speech. Prototype of glasses-mounted microphone array system to improve directionality of hearing aids.
Tippecanoe County Historical Association	On-line history quiz and memory game. On-line arrowhead classification system. Prototype of searchable image database. Prototype of a virtual tour of the main TCHA museum building. Kiosk for portable delivery of team's software. 360 degree iPIX images for use on CD-ROM and TCHA website. Searchable, web-based, database of watermarked digital images of the museum's collection and events.
Wabash Center Greenbush Industries	Machined platform to aid workers with cerebral palsy in feeding a clamp onto plastic tube. Electromechanical tube winding device. Rubber Grommet Fixture designed to make inserting rubber grommets into the modeled plastic sheets feasible for workers with physical disabilities. Clamping device for reassembly of corn sweetener filters. Shape-sorting board with electronic score-keeping and feedback, to help workers with physical and mental disabilities to develop skills.

programs will make the initiation and growth of EPICS programs easier.

RESOURCES AVAILABLE TO THE EPICS PROGRAM AT PURDUE

The most critical elements in the success of an EPICS program are leadership of the program by one or more faculty members and support by the appropriate departmental and college administrators. This ensures that a high-quality design and service learning experience will be provided to all EPICS students in courses that are approved by the faculty. Beyond these essential elements, the level of student enrollment in EPICS depends upon a combination of degree requirements in different disciplines, available space, the number of potential faculty and industry-based advisors, and the teaching credit that is offered for advising an EPICS team. Note that the number of potential project partners is typically not a limiting factor—contacts with the community, around the university, and with local government agencies yield as many projects as desired.

Operational needs are in three broad areas: staff, space/facilities and project expenses. Personnel to support the EPICS program include team advisors, teaching assistants, and administrative staff. The level of advisor and TA support is matched to the support provided for senior design courses. At Purdue, faculty who advise an EPICS team for one academic year (approximately 48 student credit hours) receive teaching credit equivalent to teaching a traditional 3-credit, one-semester course. A half-time TA provides administrative support for three to four teams and provides program-wide technical support as a consultant in his/her area of expertise. Administrative support varies with the size of the program. Purdue's EPICS program, with 300 students on 24 teams each semester, is led by a faculty director and co-director, with staff support for program operations and facilities management.

Space requirements are for team meetings, lectures and presentations, and project development. Class/meeting rooms that can be configured for large-group discussions support the teams' scheduled two-hour weekly meeting. The equipping of the meeting rooms with networked computers facilitates access to on-line resources and filing of weekly reports. Computers and data projectors support design reviews and presentations to community partners. A large lecture hall is used for the weekly, one-hour EPICS lecture and for the teams' end-of-semester presentations. Lab needs depend on the types of projects being undertaken by the teams. At Purdue, flexible prototyping labs with evening and weekend access have been effective in supporting a wide range of electrical, electro-mechanical, and software projects.

The area in which EPICS resource needs differ most greatly from traditional design courses is in acquisition of equipment and parts for projects that will be deployed in the community. For typical projects, expenses for prototypes and proof-of-concept systems are borne by the university. Once a system has been proven, the EPICS team may work with the community partner to raise funds (e.g., from a community foundation) for larger-scale deployment. Based on over 300 team-semesters at Purdue, annual expenses average approximately $1500 per team per year. This is supported primarily by corporate sponsors.

Additional resources and staff are available for the National EPICS Program and the EPICS Entrepreneurship Initiative, both of which support the activities of all EPICS sites.

CONCLUSION

The Engineering Projects in Community Service Program has added several new dimensions to the educational experience of engineering undergraduates at Purdue University. These include vertically-integrated, large-scale, multidisciplinary design teams; multi-year student participation that enables them to experience all phases of the design process; and large-scale design projects in a service-learning context. Each EPICS team thus functions as a small, but highly capable, engineering design firm with a real customer—its project partner from the community. EPICS teams' ability to define, develop, and deliver ambitious projects to their partners in the community has fostered lasting relationships with the community and a high level of mutual commitment. This emphasis on multi-semester, multi-disciplinary, customer-driven design in the community context has made EPICS a good match for the ABET EC 2000 criteria [25].

The program has demonstrated success through student and community partner evaluations and retention. Data from student evaluations demonstrate that EPICS is a model where professional skills, including teamwork and communication, can be learned while participating in realistic design teams. The continued growth in terms of numbers of students and numbers of projects is an indicator of the success of the program and the needs it is meeting. The adoption of the EPICS model by 14 other institutions demonstrates that the EPICS model transcends campuses.

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