University and Community Partnerships for Reaching Pre-College Students: The EPICS Model

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Introduction

Mathematics and science are creations of the human mind and, as such, are continuous enterprises[1]. Many young students possess the innate ability to think and reason mathematically[2] and most children possess a level of curiosity about the world around them[3] Yet, the commitment by the engineering and educational professions to ensure that these early engineering tendencies develop and are sustained throughout the P/K-12 learning experience has been primarily intermittent. These periodic and ad hoc efforts are insufficient. Needed educational change and consistency are necessary if the engineering profession is to overcome its challenges specifically in undergraduate enrollment numbers, recruitment of women and under-represented minorities, and the public perception (including the views of youth) of engineering and technology. There is interconnectivity among science, technology, and engineering that requires clarification and promotion. Science seeks to understand the natural world and requires new tools and discoveries; engineering uses scientific discoveries to create products and processes that meet society's needs; technologies are the result of engineered designs created to solve societal needs and wants[4] These common threads can be strengthened when educational solutions and opportunities for engagement are consistently, creatively, and thoughtfully applied.

In8, the Engineering Projects in Community Service (EPICS) Program at Purdue University was created to provide undergraduates with a real design experience within a service-learning context. EPICS teams perform their designs within four main areas of focus: 1.) Education and Outreach, 2.) Access and Abilities, 3.) Human Services, and 4.) Environment. Included within the realm of Education and Outreach is a concerted effort to focus on the integration of engineering within the P/K-12 community by unifying, over an extended period of time, the educational preparation of undergraduate engineering students with their pre-college cohorts; who are at the threshold of their technical curiosity, creativity, interest, and skill development. Under the guidance of faculty and industry advisors the results of this linkage have been systems that have a significant, lasting impact on community partners and the people they serve[5,6] These types of pre-college engineering influences offer a vehicle for applying mathematics and science to students' real world experiences, developing a sense of the creative aspects of engineering, and showing how working in teams contribute to achieving goals[7].

Via formal and informal educational venues, the EPICS program serves the P/K-12 teachers, other educational professionals, students, and undergraduates (within and outside of engineering) to provide technical solutions for the community. It is the goal of the authors to specifically focus on EPICS' pre-college initiatives. This paper describes the reciprocal, formal, and informal alliances EPICS has with four key P/K-12 entities encompassing elementary, middle, and high schools levels via the: 1.) Imagination Station, a local interactive science and technology museum in the development of interactive displays; 2.) Klondike Elementary School, whereby infrastructure is provided that can be used for a variety of learning activities at multiple levels; 3.) Happy Hollow Elementary School, an upper elementary/middle school environment, in the creation of an inquire-based engineering classroom; and 4.) Bedford North Lawrence High School, in which EPICS alumni have created a similar model for high school students aspiring to become engineers.

The EPICS Program

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. This program is a multidisciplinary (composed of students from 20 disciplines), vertically integrated (freshman-senior), engineering-based series of design courses. Each EPICS project involves a team of eight to twenty undergraduates, a not-for-profit community partner – for example, a community-service agency, museum or school, or government agency - and a faculty or industry advisor. A pool of graduate teaching assistants from seven departments provides technical guidance and administrative assistance. Currently, the Purdue EPICS program has 29 teams (over one third of which serve pre-college needs) with over 400 students participating during the 2004-2005 academic year. EPICS teams work in four areas of the community, access and abilities, education/outreach, social services and the environment. This paper will focus on the teams involved in education and outreach but descriptions of all of the teams can be found on the EPICS web site at http://epics.ecn.purdue.edu. There are also 14 other universities with EPICS programs, listed at http://epicsnational.ecn.purdue.edu

The EPICS model for service-learning seeks a balance between the learning experience of the students and the services it provides to the local community. To improve the experience for the students and the community partners and produce better designed projects, the EPICS program has adopted a systematic approach to managing all of the designs. Each EPICS team is constituted for several years, from initial project definition through final deployment. Once the initial project(s) is completed and delivered, new projects are identified by the team and community partner 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 grants 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 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 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.

Evaluations of the EPICS Program have shown that it provides a rich environment for acquiring the skills articulated in ABET's EC 2000. EPICS has been shown to attract a higher percentage of underrepresented students within the fields of engineering and the overall retention rate from one semester to the next has been over 77%[8] This factor reinforces the program's goal to sustain long term partnerships enabling relationships and projects to fully develop. The high percentage of returning students is evidence that EPICS students desire to pursue the curricular blend of sound engineering design while simultaneously providing real, needed benefits to the community.

A Reciprocal Model of Engagement

The EPICS model provides a reciprocal service-learning structure that supports long-term projects in which teams of undergraduates, generally within engineering, are matched with community agencies and P/K-12 institutions that require technical assistance. Under the guidance of faculty and industry representatives from several disciplines, EPICS teams work closely over many years with their community partners to define, build, deploy, and support the systems needed. The results are systems that have a significant, lasting impact on the community partner and the children and adults for whom they serve.

EPICS has successfully engaged faculty and practicing engineers with undergraduate student teams to establish mutually beneficial relationships with local schools, museums and university outreach organizations. These experiences provide long-term technical support and create opportunities for pre-college students to interact with undergraduates in engineering in settings not traditionally linked to engineering.

Parents, teachers, administrators, and community leaders servicing elementary, middle, and high school students have collaborated with EPICS' industrial experts, undergraduate engineering students, and professors to develop needs-based projects that motivate and engage young students to excel in science, mathematics, engineering, and technology. The literature reinforces these types of relationships noting that the elementary school is the most effective level for sustaining inherent inquiries or intervening to improve attitudes, higher achievement, and increased access in science for young learners[9] particularly for girls[10]. Additionally, teachers are the key to changing the way mathematics is taught and learned.[11] It is clear that students need opportunities for both practice and intervention and when students discover mathematical ideas and invent mathematical procedures; they have a strong conceptual understanding of connections between ideas[12]. Further, providing problem-rich situations and encouragement to seek and share solution-based methods solidify student performance.[13] These positive youth-centered relationships are an excellent foundation for improved student performance for both the P/K-12 and undergraduate students.

The educational partners further benefit by receiving valuable interactive and inquiry-based advisement, equipment, curricular or need-based instructional materials which are aligned with state and/or national standards and in concert with the vision and mission of the educational agency. These advantages are positively compounded over time as the articulation between the community partner and EPICS becomes seamless, team members' mature, projects and designs evolve, and the professional relationship solidifies at a professional and educational level.

These relationships provide an environment for undergraduates to earn academic credit towards their respective degrees, over several semesters, with educational institutions while also reinforcing the specific instructional needs and goals of the P/K-12 partners. The goals and merits of this program have guided the development and mastery of critical thinking, problem solving, and technical skills among children, youth, and undergraduates participating within the program. Originally, EPICS' pre-college interventions were subtle: Supporting technical needs, offering professional knowledge, and building mutually beneficial relationships. As the EPICS program has matured and the P/K-12 relationships strengthened, the program's achievements have formulated a model of best practice which may guide our profession to systemic and meaningful change in the manner by which we teach, mentor, and retain young engineers.

P/K-12 Partnerships

EPICS is a living and fluid organization whose nearly 30 long-term alliances and over a 150 delivered projects thrive on social change that guides further intellectual and professional growth for all who participate within the program. Four diverse P/K-12 partnerships and their unique hallmarks are described for this discussion based on their commitment to the preparation of young engineers and the challenges and successes that enabled them to achieve their varied goals.

Imagination Station
Community Science and Space Museum Partnership – Lafayette, Indiana

The Imagination Station (IS) is a hands-on, interactive children's science and space museum located in Lafayette, Indiana. Its mission is to provide a place for children and their families to explore the worlds of science, engineering, and technology through interactive displays, activities, and workshops. The museum opened in 1996 through the efforts of a volunteer community organization.

The Imagination Station EPICS team began in 1997 that jointly served IS and an elementary school. In the fall of 1998, the teams were split and one team was dedicated to IS with a second team added in 1999. The goal of the teams is to create interactive displays that enhance the ability of the Imagination Station to accomplish its mission. The teams have consisted of students from disciplines including electrical, computer, mechanical, materials, aerospace, chemical, and civil engineering, computer science, sociology, and visual design. Purdue faculty members as well as engineers from Eli Lilly Co. and Rea Magnet Wire Co. have advised and supported the teams. The practicing engineers have brought real world experience to the teams.

The teams have worked with the director and IS staff to develop several exhibits. The teams have learned to consider safety and reliability issues in the hands-on children museum environment. The teams have learned that 1) children play hard with the displays and 2) are very creative in using parts of the displays they were never intended. These real constraints have added complexity to the designs and improved the design education of the undergraduate participants.

Students have to design for the children to come to IS., taking into account factors such as their size and height. IS teams have also had to learn about educational displays. Early in the program, students designed complex and interesting devices that were not as engaging for the children as they could be which meant that the children might not to spend enough time with the display to learn the concept behind the technology. The students have had to evolve their thinking and design processes to understand the learning objectives of each display and to integrate educational materials, such as signage, into the design of the display early in the process. To really understand what the children will do and what they are interested in, most students spend time at IS observing and volunteering with their after school and special programs.

The results have been very positive with several projects being delivered to IS. These projects include:

- History of computers – a hands-on collection of hardware and software games showing the evolution of the personal computer.
- Computer operation – an interactive matching game that quizzes children on the components of a computer. The display is run by a computer housed in a clear plastic case so that the child can see the actual computer components as s/he plays the game.
- Mechanical gearing – an interactive display with a modified bicycle that allows children to power a series of lights that show the energy the child is generating.
- Electromagnetism – a series of three exhibits that demonstrate the principles of electromagnetism:
  - Applications display – a static display of common uses of electromagnets, including a microwave oven and an electric motor.
  - Mag Tower – an interactive display that encourages children to explore the properties of magnets by stacking permanent magnets on an electromagnet that they can turn on and off, vary the current and reverse the polarity.
  - Mag Racer – a 7-foot-long interactive display that challenges children to move a car equipped with a permanent magnet down a track by activating a series of electromagnetic coils distributed along the track.
- Windtunnel – a windtunnel with removable test section houses interactive modules that demonstrate lift and drag. Children can launch text objects into the airstream of the test section and observe the affects of lift or drag.

- Wellhead Protection and Water cycle – an interactive display shows the progression of pollutants through the soil and into the groundwater wellheads along with the water cycle on the surface. Water and pollution movements are shown with LED's.
- Mixer – density is demonstrated with an interactive exhibit that allows children to mix colored tanks of water and oil and observe their mixing and separation in a settling tank.

The EPICS teams have continued to be integrated into the operation of IS which also serves as a science resource for area schools. Many schools use facilities like IS to insure they meet state science standards. These standards and the use of the exhibits to meet these standards become part of the design constraints. An example of this is the Wellhead Protection/Water Cycle project. Initially, it was prototyped to only illustrate ground water contamination of the wellhead based on a partnership with the area Wellhead Education Committee and IS. The team found that IS teaches the water cycle as part of its science outreach curriculum. The team found it easy to integrate enough of the water cycle into the final production version to allow IS to use the interactive display in their standard science curriculum.

Most displays are designed so that the children can also see the inner workings of the exhibits. Many of the EPICS students spend time at IS working in their programs and observing how children use the exhibits and have the opportunity to talk to the children about how the displays were designed and built and how they function.

The six year relationship between IS and EPICS has allowed each to understand the other's needs and capabilities. The work of the EPICS students has enhanced the informal learning environment of IS and the formal curriculum modules that the staff uses for their programs. It has also provided first hand and visible examples of how engineers can work on fun projects for children.

> *EPICS has provided Imagination Station an avenue to explore exhibit ideas with creative and talented young people who have an understanding of the technical skills needed to make the ideas into reality. The teams have also provided research capabilities and technical assistance that we would not otherwise have been able to afford. Helping the team members understand what "hands-on" entails has made the staff analyze more closely what constitutes good museum practice. We have all gained skills and insight through the process.* **Barb Pipher-Doran**, *former director of the Imagination Station*

Klondike Elementary School
Preschool/Elementary School Level Partnership– Tippecanoe County, Indiana

Our second highlighted partnership started in 1997 with an elementary school, Klondike Elementary School is the largest elementary school in Indiana where over 800 students attend kindergarten through fifth grade. Its proximity to Purdue University provides for a diverse base of domestic and international students many for which English is a second or third language. The school is well postured for technological advances. It is fully wired for internet access and media retrieval. Various computer labs and classroom technologies are common place. The primary goals for the Klondike Elementary School (KES) partnership were designed to serve multiple grades, large numbers of students and teachers, for a variety of purposes.

One such project was known as *The Stoplight* and was designed to serve as a behavioral management tool for teachers and staff during daily lunch periods within the cafeteria. Students met often with school personnel and developed a "stoplight" that is programmed to change between red, yellow, and green based on the ambient noise level of the cafeteria. A manual option was also incorporated if the teachers want it to move to red for quiet. The "stoplight" has also been used as an instructional device by teachers to describe electrical, computer, and mechanical engineering concepts.
KES also requested various devices that would support the academic preparation of its students for various local, state, and regional competitions. One mechanism was an instructional tool entitled *Quiz Bowl*. Similar to today's television game shows, this activity-based instrument is a wireless buzzer system that allows students to acknowledge an answer in the venue of friendly competition. This tool is used in multiple classrooms, at school-wide events, for practicing facts or concepts, and generally providing a fun learning device in whatever way the teachers and children desire. It provides teachers with another tangible example of how engineers can help.

A fairly sophisticated piece instructional software known as a *Spell Bowl Simulato*r was also created by EPICS students. This invention aides KES students in the preparation of the Indiana Spell Bowl as they develop a vocabulary by spelling and defining new words in an automated and captivating manner. The students are introduced to words through audio pronunciations and usage within a sentence and have 20 seconds to enter their spelling of the word. The spelling is confirmed and either approved or corrected providing immediate feedback. Teachers are able to input new words and audio, corresponding sentences, and definitions into the master database, which will be located on a central server.

Happy Hollow Elementary School
Elementary/Middle School Level Partnership -, West Lafayette, Indiana

An interactive, inquiry-based elementary engineering classroom is the hallmark of the Happy Hollow Elementary School (HHES) alliance. Happy Hollow is the sole upper elementary/middle school within the West Lafayette, IN public school district. Children range in age from nine to twelve, attend grades four through six, and represent nearly every language and country throughout the world. Due to the composition of the West Lafayette community and its educational and research influences, this district consistently ranks within the top two school corporations in academic achievement within the State of Indiana. High student achievement through innovative teaching strategies with current technologies is fundamental to the expectations of the administrators, parents, teachers, and citizens of this community.
The school boasts extensive technical and learning environments including a functional television station, computer facilities, and ISDN line connections to every classroom.

To HHES team goals compliment these expectations and seek to:

- Promote an interest in engineering by designing, testing, and delivering creative engineering based learning projects and related instructional materials, identified by the educators within the school, and in alignment with required curricular and academic standards,

- Improve the engineering facilities at the school.

- Interact with HHES students in their classrooms, during science clubs, and other one on opportunities meant to better understand how children learn and what engineering tendencies they may posses that can be better served via the EPICS efforts.

- Motivate children to learn.

- Glean professional and societal values and knowledge from the science educators within the school and the learning environment overall.

- Demonstrate engineering skills through ethical behavior, professional presence and communication, technical skills, and quality projects.

This team's achievements include 20 professional quality engineering and science activities. Each activity is educationally supported with instructional materials that linked to the required learning goals, curriculum and academic standards and are integrated into the science teaching practices.

> "A trip to a hands-on science museum is guaranteed to capture student interest and keep them involved," says Sherry Anderson, Master Educator at Happy Hollow. She adds, "Unfortunately, not all schools are in close proximity to such a facility - the next best thing would be a museum right in your school with models that demonstrate physics and other concepts I am teaching. We're fortunate to have this partnership and our students are the beneficiaries."

Long standing alliances such as this can only be successful with the knowledge, dedication, and professional support of the classroom teacher. Ms. Anderson and her colleagues are committed educators that ensure that all students have an opportunity to learn and grow – including our young college engineering men and women. Teachers value the EPICS' contributions and often speak of the motivation the team's presence offers to their own professional development and pleasure.

The students who enroll for the HHES team do so for a very simple reason: To help children learn and appreciate engineering. Each member of the HHES team has chosen to engage with this particular partner. Many of the engineering students on the HHES team have younger brothers and sisters, enjoy working with younger students, have been influenced by a teacher to enter the profession, realize that engineering can be fun, and truly desire to create, design, manage, finance, and deliver their own designs for those who would appreciate it most – the kids!

As the advisors for this team will acknowledge, this group of undergraduate students are proud of their growth and value their results. They have learned to recognize and apply the EPICS model, through the mentorship of others, by creating safe and durable projects that reflect a design process that professional customers and community partners require. Some of the team's recent accomplishments include:

Weather Station: The objective of the Weather Station Project is to develop and implement weather tracking equipment and data collection procedures. An interactive web page which highlights data from the weather station is a component of the project of this and a related venture, the UV Sensor, began in Fall 2002.

Robotic Arm: The purpose of this project is to develop a robotic arm to educate the students about introductory concepts of robotics, feedback mechanisms thru the use of a manual input controller, and the anatomy of a human arm.

Air Cannon: This effort is mobile cannon that will eject a tennis ball over a long distance. This project will promote learning goals within physics via projectile motion.

Memory Game: This game is modeled after a Pop-A-Shot based exhibit that via the use of distorted goggles demonstrates some of the important principles behind learning such as: differences, memory, and repetition.

Laser Harp: The laser harp is a musical instrument that can be played by passing a hand through an array of photodiodes. The use and production of lasers and its related technologies are conveyed via a fun and innovative interaction.

Other deliverables include: Simple Machines, Tornado Box, Rain Forest, and Van De Graff Generator and other interactive engineering designs relevant to HHES' needs.

The quality of this team's products and is a direct result of the curricular strength of the EPICS model. The advisors ensure that the strategies and expectations inherent within the program are respected and understood by the undergraduate students and that the team's interactions, goal setting, documentation, and communication with the community partner reflect these guidelines. These and the professional collegiality provided by the educators within Happy Hollow Elementary School have resulted in a fully functioning partnership – worthy of noting and eager to grow and learn together.

Bedford North Lawrence High School
High School Level Partnership– Bedford, IN

The EPICS program engages undergraduates in EPICS courses across 15 universities nationally. We have highlighted how these programs can partner with P/K-12 programs. An extension of the National EPICS Program has been the dissemination to the first high school in a pilot program at Bedford North Lawrence (BNL) High School. The program was initiated by two EPICS alumna who found themselves in discussions about how to increase interest in engineering among high school students. They recalled their experience in EPICS and felt that it provided the kind of experience students needed to really see engineering in practice. With the Support of their employer, Crane Naval Surface Warfare Center and the local American Society of Naval Engineers (ASNE) chapter, they established a contact with a physics teacher at Bedford North Lawrence High School in Bedford, Indiana. The high school program is a hands-on approach and through service learning can appeal even to those who might not have considered engineering.

The program is open to all high school grade levels of students attending Bedford North Lawrence High School. Students from the adjoining vocational school are also invited and have proven to be invaluable in terms of practical knowledge. The BNL EPICS program to date has drawn a majority of seniors. There are a few juniors each semester, as well. The future goal is to involve more students who are at earlier stages in their high school careers. The intent of this program is to provide credit for the students; however it is currently an extra-curricular, after-school activity.

The first project was to design and develop a device to help people with neurological disorders that do not have the automatic swallow reflex to remember to swallow. OLJMG Joint Services, the special education branch of North Lawrence Community Schools, is the community partner for the project. It is estimated that there are at least 20 people in the service area that would benefit from this project. In particular, an elementary school student with cerebral palsy will have the opportunity to be more fully integrated into a normal classroom because of this project.

Even though this engineering project that involves students that have had no previous engineering experience, a working prototype was finished in the first two semesters of this project's existence and the team has obtained a provisional patent for their work. The team also participated in the EPICS Idea to Product (I2P) competition along with teams of undergraduates. (http://ims.ecn.purdue.edu/entrepreneurship/index.html) The BNL team placed third in the competition with undergraduates from some of the other EPICS programs.

This success is due much to the students from the electronics courses at the local vocational school. The different backgrounds of the students have enforced the need for teamwork; the whole is greater than the sum of the parts. These students have been driven by the thought of helping other students and have benefited by having the opportunity to meet one of the potential users of this project. After meeting the student, work dramatically increased.

The main goals of this EPICS program are to increase community awareness and to provide exposure to engineering as a career prior to the collegiate experience. This first project has shown students many of the constraints facing design engineers. Each implementation of this project idea will be different depending on the people involved, geographical location, etc. The program has the potential to be a highly effective high school course that would instill a larger worldview to pre-college students. This model exposes the high school students to actual engineering design to address social and human issues, with the mentorship of practicing engineers. All of the initial assessments of the program have been positive. Follow-un studies are planned to fully assess the impact of the EPICS program in the high school setting.

Conclusions, Implications, and Next Steps

Within the EPICS Program we have observed positive outcomes that have potential for an increased and formalized engineering education influence within the P/K-12 community. Additionally, we have seen how the EPICS model for undergraduate design education can be transferred into a high school environment. We know that: An informal and subtle engineering presence can originate as early as preschool; increasing the volume and occurrence of engineering concepts and skills as diverse children progress throughout the elementary grades is necessary to sustain curiosity, interest and knowledge over time; engineering education has the potential for curricular and standardized integration within the middle and high school levels.

These pre-college essentials may enable engineering undergraduate and graduate programs to recruit and retain those most diverse, creative and qualified to enter our Colleges of Engineering throughout the next ten years. Additionally, our future engineering graduates and their innovative products may be results of increased social awareness, thus, ensuring effectiveness in the field while an awareness of social needs emerges and is reinvested for the greater good. Further, the P/K-12 community will be the beneficiary of these innovations ensuring the development of engineering education teachers and the integration of engineering education within curricular and academic standards will permanently occur.

The social and human context of the EPICS design projects offers a rich environment for students at each level throughout the pre-college through college continuum. The development and sustenance of these purposeful and educational relationships within the context of EPICS is a model of best practice worth developing further and considerations for EPICS-like alternatives to align with varied curricula and academic standards are worth pursuing. We are convinced that these experiences provide multiple pathways in which to learn about engineering and the compelling human issues of today's society.

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