121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014
Paper ID #9871

Integrating Community Engagement, Freshman Chemical Engineering, and an AIChE Student Chapter

Dr. Bill B Elmore, Mississippi State University

Bill B. Elmore currently holds the Hunter Henry Chair and Associate Directorship in the Swalm School of Chemical Engineering at Mississippi State University. In his twenty-fourth year of engineering education, Bill focuses on project-based learning at all levels of the undergraduate chemical engineering curriculum and undergraduate research in energy and micro-scale reactor studies.

Integrating Community Engagement through AIChE with a Problem-based Freshman Chemical Engineering course

Abstract

The focus of this paper is the development of a program integrating regular community engagement activities with a two-course freshman chemical engineering sequence and the regular activities of the student chapter of the American Institute for Chemical Engineers (AIChE).

While the community engagement mission of our AICHE chapter spans a variety of organizations and activities (e.g. Habitat for Humanity, Salvation Army, and city Parks and Recreation projects) the LEGO® NXT robotics system has served as a key component in our K-12 outreach program, our freshman chemical engineering classes and as a means for engaging our chemical engineering students in service learning activities.

This integration of activities, all surrounding the LEGO™ Robotics system (coupled to Vernier® sensors and probes and "in house"-designed apparatus) has engaged students at all levels, from middle school through chemical engineering seniors in an exciting, "studio-based" environment. Anecdotal evidence suggests students readily "latching onto" key concepts and various aspects of engineering through this "multi-modal" learning approach. Objectives of this method of program integration include: 1) strengthened recruiting of students to engineering studies, 2) better "visualization" of engineering concepts among chemical engineering freshmen and 3) a stronger sense of the need for life-long learning and community service among our engineering undergraduates.

Introduction

Service-learning has been a long-standing feature of many academic programs and is, increasingly, an accepted pedagogical approach to achieving learning outcomes in the classroom. Resources abound for enabling the incorporation of service-learning into traditional courses.[1-3] Our chemical engineering program has sought to strengthen student engagement in service learning over the past nine years through an evolving integration of the problem-based activities comprising our first-year experience and the strong community outreach component of our student chapter of the American Institute of Chemical Engineers. Patterned after *Learning through Service* activities around the United States[4-6] and the *EFELTS* project[7-8], we seek: 1) to strengthen our outreach activities by taking a more rigorous research approach, 2) to encourage our chemical engineering students to use their growing intellectual talents and natural abilities to contribute more to society, in general, and, 3) to contribute to the broader vision of integrating service learning as an accepted part of engineering education.

Examples of Community Engagement

Toward these aims, several examples of our service-learning activities are presented to illustrate the community-service orientation of our AIChE student chapter and its contextualization with

the development of a parallel problem-based freshman year in our chemical engineering program.

Coupled to our service learning goals is a strong desire to develop engagement activities that are supportive of current STEM K-12 standards. Without belaboring the well-documented needs for raising student performance with regard to educational standards, it is sufficient to state that, at every point possible, educationally-oriented outreach efforts emanating from engineering educators and their students must seek relevancy and alignment with established STEM standards appropriate to the audiences targeted. With this in mind, we continue to refine our activities to be supportive of state math and science standards—now under consideration through efforts such as the "Common Core State Standards Initiative".[9]

Examples of skills around which we are shaping our outreach activities may be found in the 2014 draft of the *Mississippi College- and Career- Readiness Standards for Mathematics*.[10] These include:

- Make sense of problems & persevere in solving them
- Reason abstractly and quantitatively
- Construct viable arguments and critique the reasoning of others
- Model with mathematics
- Use appropriate tools strategically
- Attend to precision

These generalized skills and others, more specific to engineering design and problem solving mesh closely with our learning objectives established for our chemical engineering freshmen.[11]

The following scenes describe, in a general overview, a variety of activities we have conducted through our AICHE service learning program. Each of these have been inspired directly from the work I have developed in the problem-based a freshman year in our chemical engineering program.

Scene I

The room is filled with noise, as a dozen or more middle school-aged Girl Scouts in one corner try to "scream" their racing robots across the finish line, driven forward by programmed responses to microphone inputs; while, in another room a second group is quietly experimenting with the effects of environmental pollution and deforestation, as their robotic "creatures" respond with increasing distress to the removal of protective plant life. Elsewhere, another team investigates a LEGO™ robot's ability to negotiate an incline when given various surface treatments. The engineering undergraduates coaching the Scouts through the morning's events are all smiles and obviously proud of the Scout's accomplishments as they rotate through the morning's merit badge stations.

Figure 1. Girl Scout Day

Scene II

We peer into a classroom early one Saturday, and see a group of middle school students intently focused on the morning's robotic challenge while their freshmen engineering coaches stand at the ready for the construction or programming questions that may arise. The quietness and focus of the paired teams is as notable as the enthusiastic shouts and laughter of those in the first scene.

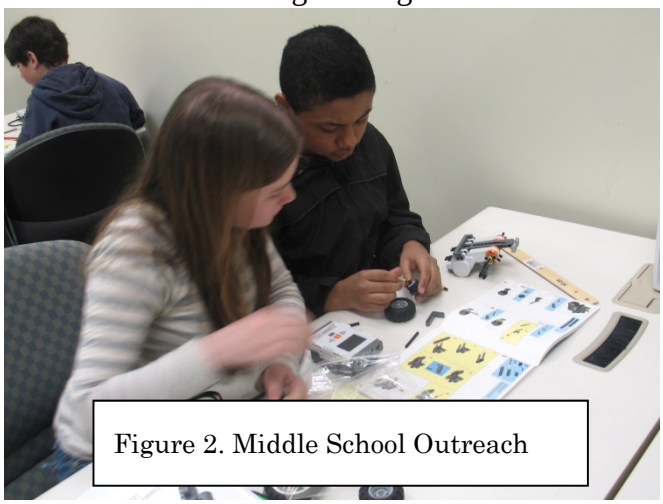


Figure 2. Middle School Outreach

The experiments with various gear ratios, speed and wheel circumference momentarily induce a few yawns among the participants, but the coming contest of "robot football" keeps heads thinking and LEGO™ parts flying to produce a "star player" by the time of the competition.

Scene III

The class of 60 perks up noticeably when I cease my instruction on using Microsoft Excel® for experimental data management and wheel in carts loaded with LEGO™ robotics kits, telling everyone to get into their teams and begin their first team design challenge. Initially, I spend a good bit of time mentoring teams and working to help balance those *legomaniacs* (and their tendency to dominate the project) with those more hesitant to step out into unfamiliar territory. Within a week, I have to caution some to not let their calculus, chemistry and physics "slide" while spending an inordinate amount of time outside of class on their projects. Team dynamics are continuously improving and, through shared *team leader*, *cheerleader* and *data keeper* roles, I can observe obvious growth of many individuals in their confidence levels and abilities to be a team player. By the end of the semester, projects range from a "processing station" to model wet etching of silicon wafers to a multi-tank system for producing a "chemical product" at a constant rate and quality.

Figure 3. Boy Scout Day

Each of these "real-life" scenarios has played repeatedly in sections of the Freshmen Chemical Engineering Problem Analysis course and through many of our students' participation in our AIChE K-12 outreach efforts.

Uniquely positioned through my freshman teaching assignment (i.e. CHE 1101 Freshman Seminar each fall and CHE 2213 Problem Analysis each spring) and service as Faculty Advisor of our heavily service-oriented American Institute of Chemical Engineers (AIChE) student chapter, I have been able to team up with my students to develop a program for engaging both freshmen chemical engineering majors and K-12 students in active learning through design-oriented projects with LEGO™ robotics, Vernier® sensor technology and a "supporting cast" of pipes, pumps, tubing, gears, etc.

Background

"Learning 'about' things does not enable students to acquire the abilities and understanding they will need for the twenty-first century. We need new pedagogies of engagement that will turn out the kinds of resourceful, engaged workers and citizens that America now requires."

Russ Edgerton, former education officer for the Pew Charitable Trusts (Smith et al., 2005)

Figure 4. ChE Analysis Team Design

Hands-on education

The concept of "pedagogies of engagement" increasingly finds expression at all levels of education, and, in some forms, is described variously as "hands-on" education[12], "problem-based"[13-14] or "project-based" learning[15]. Such approaches provide strong links between science and mathematics concepts and real-world problems as students "construct" new content knowledge while investigating a problem through a physical system (i.e. actual physical elements used to analyze a problem and synthesize potential solutions)[16]. As illustrated in Figures 4 & 5, we use the LEGO NXT robotics platform for engaging our freshmen in team-oriented design projects.

The use of robotics to actively engage students in learning has a strong foundation in K-20 education.[17] Robotics applications are used in a variety of higher education settings across numerous disciplines including various engineering disciplines[18-20] and at various levels from freshmen through senior classification.[21-22] Studies of courses in which robotics is featured prominently have shown positive results from such applications.[23] Likewise, robotics problem-based learning activities have been shown to be a valuable asset to K-12 classrooms useful in teaching not only STEM-related subjects[21,25] but even topics in biology[26] and values education.[27]

Figure 5. ChE Analysis Designs

Robotics technology enables teachers to elicit creativity and critical thinking from students by drawing on students' curiosity towards unknown, yet approachable physical systems.[25, 27-29]

In a pivotal report on middle school education, *Turning Points: Preparing American Youth for the 21st Century*, one recommendation stated "Middle grades schools should transmit a core of common, substantial knowledge to all students in ways that foster curiosity, problem solving and critical thinking[30]. We believe the use of robotics in our outreach program has helped to raise the level of curiosity among the K-12 groups we visit.

A further benefit is being realized through the School of Chemical Engineering's freshman engineering and K-12 outreach program in that a significant service-learning component has become a natural outgrowth of this effort to bring robotics into the classroom. The involvement of collegiates in K-12 outreach has a long-standing tradition among higher education institutions and, particularly, colleges of engineering, as an ever-increasing need for "academic intervention" has arisen with the decline in student preparation in STEM subjects pre-requisite to undertaking engineering study[31-32]. Such service learning activities can contribute to increased collaboration across the divide that often separates the engineering and science and K-12 educational cultures[33]. A "service-oriented" culture can also enrich the educational experience of engineering undergraduates. Possessing inherent strengths through a progression toward becoming ever more highly-educated, they can grow in their awareness of the responsibilities to use this preparation to become informed leaders and "service-active citizens" in their respective communities.

The Evolution of our Program

The School of Chemical Engineering K-12 outreach program has grown, in part, out of my own personal experience engaging my children in STEM-based activities during their middle school years**.** In particular, our involvement with the highly energized *First Lego League* competitions contributed to my daughter's choice to study mechanical engineering. It further led to the germination of an idea about using the LEGO™ robotics system to creatively introduce practical engineering concepts to my chemical engineering freshmen.

Figure 6. Girl Scout Merit Badge Day

Beginning in 2006, I brought LEGO™ robotics into my Chemical Engineering Problem Analysis course in an attempt to enliven the course material and better motivate student learning. Historically rooted in teaching various Microsoft Excel® and Visual Basic techniques, the Analysis course is focused on preparing students for the extensive use of these tools in later courses and in the chemical process industries. I personally found the method of working through spreadsheets in "real time" tedious and stifling to class dynamics. "Now class, if you will notice, as I execute this formula in cell ZZ149 how it changes the results in cells A45, D15 and R73…" (you get the idea). I considered a better approach—putting these tools into an "as needed" context with hands-on engineering design problems.

Figure 7. Women In Sci. & Engr.

Simultaneously, as the faculty advisor for our student chapter of the American Institute of Chemical Engineers (AIChE), I launched a service-learning initiative as a means of strengthening students' broader educational experience and as a way to draw more prospective K-12 students toward considering careers in engineering.

The marriage of our service-learning activities and the use of LEGO™ robotics became an inevitable link over several semesters as chemical engineering students' familiarity with the robotics kits grew and naturally integrated into developing interesting, hands-on activities for our K-12 outreach.

Program Structure and Activities

Over the five intervening years since the introduction of robotics technology to the chemical engineering analysis course and the current use of this technology in our K-12 outreach program, we have led a number of activities including

- Boy Scouts and Girl Scouts half-day workshops where Scouts can earn multiple STEM-oriented merit badges
- A five-week series of half-day middle school robotic building sessions for grades 4-6
- Multiple school site visits
- After school and weekend community programs

Strengths and Challenges

To many, building and operating robots looks interesting and fun, but the task of doing this can be daunting. Likewise, the underlying principles supporting the "How?", "Why?" and "What for?" may seem elusive to many. Through our numerous activities using the robotics kits we have experienced firsthand how quickly students can learn to assemble and operate this system.

Figure 8. Freshman Design

A crucial element to the introduction of any technology to the classroom is the utility of the technology. LEGO™ robotics kits are designed with engineering precision allowing users to quickly and repeatedly build prototypes of projects conceived and designed by students. Added capabilities are gained by combining the LEGO robotics technology with Vernier sensor technology—facilitating the design of experiments that not only allow the collection of data from an experiment, but allow student to program the robot to respond to the experiment with an action that accomplishes a task.

For example, one student team designed a "batting machine"; another designed a "soda dispenser" that would pour a precise amount of soft drink into a waiting cup. This "whole process" approach to STEM subjects brings learning full circle by showing the learner how the result from a given experiment can be used to accomplish a real world task. From a chemical engineering perspective, some of my freshman chemical engineering student teams have designed a system to measure and maintain tank level (Figure 8) with inflowing and outflowing

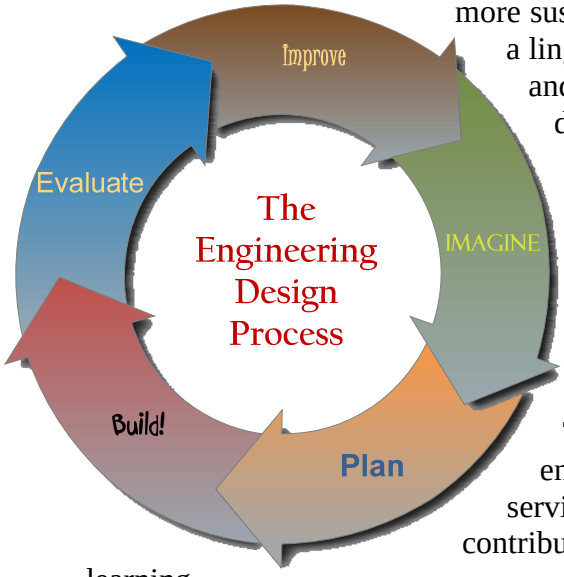
streams of water (a commonly observed phenomenon in any chemical processing plant). Using the LEGO robotics software (overlayed on a National Instruments LabView platform) the LEGO robotics microprocessor is set to control valve settings in response to the sensor-detected tank liquid level. Vernier sensors are available over a broad range of subjects in the areas of physics, biology and chemistry (e.g. accelerometers, carbon dioxide and oxygen detectors, pH and temperature sensors). These sensors readily interface with the LEGO robotics kits to allow students to design real world processes spanning an equally broad range of engineering topics.

Conclusions

In post-activity surveys, students, teachers, parents and administrators alike have responded enthusiastically to our outreach activities—many asking us to enable them to bring such advanced technology and training to their classrooms. Mississippi perennially ranks at or near the bottom of most statistical measures regarding educational expenditures per pupil. For many schools, this type of robotics/sensing technology is out of reach financially. Yet, we believe that sustained contact with schools and community venues through our outreach program can contribute to increasing the recruiting of students to engineering and science career preparation by combining sustained coaching and modeling with an integrated technology and an equally integrated curriculum spanning STEM subjects.

Figure 9. First Lego League team

As with any K-12 Outreach, there are challenges. The lack of parallel technology in many classrooms can leave students merely "teased" with the allure of such intriguing learning opportunities and no means by which to continue this problem-based learning approach in the more sustained classroom environment. That is, how can we assure a lingering benefit to students once we have "loaded the toy box and driven away"? While this question poses a major dilemma for making a lasting, systemic change, we believe, that the effort to intersect undergraduate engineering enthusiasm and experience with K-12 students is nonetheless beneficial. We all have heard (or perhaps personally experienced) that momentary contact where a seemingly small interaction made had a major effect in life's direction. Such is our hope with this approach to K-12 outreach.



The implementation of this program is successfully engaging our chemical engineering undergraduates in regular service-learning opportunities—opportunities we believe contribute substantively to their value of the need for life-long learning, and using their engineering education for making a difference in the lives of others. By approaching K-12 students with opportunities to creatively understand and apply engineering design, we believe their potential for preparing, preservering and performing as future engineers is greatly enhanced.

Assessment rubrics are being designed to quantitatively assess the impact on students in a pre- and post- assessment approach. These instruments will be used in our spring and summer 2014 outreach activities with planned Boy Scout, Girl Scout, and other K-12 student group activities and reported at the summer ASEE meeting. The rubrics are aligned with our Learning Objectives both for the freshman chemical engineering courses and for our Service-Learning activities.

References

1. http://www.unk.edu/offices/service/Service-Learning_as_Pedagogy/ Web access. 16 Feb. 2014.

2. APPLES Service Learning, *Service Learning Series: Guide to Service Learning Pedagogy,* http://ccps.unc.edu/files/2012/10/Service-Learning-Series_Guide-to-Service-Learning-Pedagogy.pdf, Univ. North Carolina, Chapel Hill, Web access 16 Feb. 2014.

3. *Faculty & Instructors Guide to Service-Learning*, Community Service-Learning Center, University of Minnesota, https://assets.cla.umn.edu/wbaq/.../facultyGuidetoServiceLearning.doc, Web access 16Feb. 2014.

4. Swan, C.; K. Paterson; O. Pierrakos; A. Bielefeldt; and B. Striebig; *ISES—A Longitudinal Study To Measure the Impacts of Service on Engineering Students,* AC 2011-1328, 17 p.p., presented at the 2011 annual American Society of Engineering Education conference, Vancouver, B.C.

5. Pierrakos, O.; A. Zilberberg; C. Swan; A. Bielefeldt; K. Paterson; and, J. J. Duffy; *Faculty Survey on Learning Through Service: Development and Initial Findings*, presented at the 2012 annual American Society of Engineering Education conference, AC 2012-5229; San Antonio, TX.

6. Bielefeldt, A. R.; K. Paterson; C. Swan; J. J. Duffy; O. Pierrakos; and, N. E. Canney; *Engineering Faculty Engagement in Learning through Service Summit: Best Practices and Affinity Mapping*, presented at the 2012 annual American Society of Engineering Education conference, AC 2012-4531, 16 pp., San Antonio, TX.

7. Swan, C.; J. J. Duffy; K. Paterson; A. R. Bielefeldt; and O. Pierrakos; *The EFELTS Project—Engineering Faculty Engagement in Learning Through Service*; presented at the 2011 annual American Society of Engineering Education conference, AC 2011-1324, 14 p.p., Vancouver, B.C.

8. Swan, C.; A. R. Bielefeldt; K. Paterson; D. O. Kazmer; O. Pierrakos; A. Soisson; and, B. G. Tucker; *Workshops for the Engineering Faculty Engagement in Learning Through Service (EFELTS) Project: Development and Initial Findings*, 12 p.p., presented at the 120th ASEE Annual Conference and Exposition, Atlanta, 2013.

9. Common Core Standards Initiative for Mississippi--Draft, http://www.mde.k12.ms.us/curriculum-and-instruction/curriculum-and-instruction-other-links/common-core-state-standards, accessed Feb 16, 2014.

10. Common Core Math Standards for Mississippi—Draft, http://www.mde.k12.ms.us/docs/curriculum-and-instruction/new-2014-ms-ccr-standards-for-mathematics-(grades-k-12)-draft.pdf?sfvrsn=0, accessed Feb 16, 2014.

11. Elmore, Bill B., *A freshman design course using LEGO® NXT Robotics*, **Chemical Engineering Education**, Spring 2011, **45:2**, pp. 86-92

12. Johnson, S. H., Luyben, W. L. and Talhelm, D.L., "Undergraduate Interdisciplinary Controls Laboratory", *Journal of Engineering Education*, **84**, (2), pp.133-136, (April 1995).

13. Hmelo, C. E.; *Problem-based Learning: Development of knowledge and reasoning strategies*, in Proceedings of the 17th Annual Conference of the Cognitive Science Society; Pittsburgh, PA; 1995; pp. 404-408.

14. Yu, Chung Y. and David T. Shaw; *Fostering Creativity and Innovation in Engineering Students*; 2006 International Mechanical Eng. Edu. Conference; Beijing, China; March 31-April 4, 2006; www.asme.org/Education/College/2006_Proceedings.cfm

15. Barron, B. J., D. L. Schwartz, N. J. Vye; A. Moore, A. Petrosino, L. Zech, J. D. Bransford, and The Cognition and Technology Group at Vanderbilt; *Doing With Understanding: Lessons from Research on Problem- and Project-based Learning;* The Journal of the Learning Sciences; Vol. 7, No. 3/4, 1998, pp. 271-311.

16. Beer, R. D., H. J. Chiel and R. F. Drushel; *Using Autonomous Robotics to Teach Science and Engineering;* Communications of the ACM; Vol. 42, No. 6; June 1999; pp. 85-92.

17. Erwin, Ben; Martha Cyr; and Chris Rogers; *LEGO Engineering and RoboLab: Teaching Engineering and LabVIEW from Kindergarten to Graduate School;* http://www.ni.com/pdf/academic/us/journals/ijee_05.pdf

18. Rosenblatt, M. and H. Choset; *Designing and Implementing Hands-On Robotics Labs*; IEEE Intelligent Systems, Nov/Dec 2000; pp. 32-39.

19. Williams, A. B.; *The Qualitative Impact of Using LEGO Mindstorms Robots to Teach Computer Engineering;* IEEE Transactions on Education; Vol. 46, No. 1; February 2003; p. 206.

20. Elmore, Bill B.; *Using LEGO MindstormsTM to teach Chemical Engineering Problem Solving*; presented at 2007 AIChE national meeting, Salt Lake City, UT, November, 2007.

21. Elmore, Bill B., *A freshman design course using LEGO® NXT Robotics*, **Chemical Engineering Education**, Spring 2011, **45:2**, pp. 86-92

22. Wang, Eric; *Teaching Freshmen Design, Creativity and Programming with LEGOs and LabView;* presented at the 31st ASEE/IEEE Frontiers in Education Conference; October 10-13, 2001; Reno, NV; Session F3G; pp. 11-15.

23. Moor, S. S. and P. R. Piergiovanni; *Using Lego-based Classroom Laboratory Kits for Learning Process Control;* presented at the 2003 American Institute for Chemical Engineers (AIChE) Annual Meeting; San Francisco, CA; Session 348d; November, 2003.

24. Pomalaza-Raez, C. and B. H. Groff; *Retention 101: Where Robots Go…Students Follow*; J. Eng. Edu; January 2003; pp. 1-6.

25. Genalo, L. J., M. Gallagher, and J. Golder; *An Engineering Linkage to K-12 Teachers;* Session 3453; Proceedings of the 2001 American Society for Engineering Education (ASEE) Annual Conference; 2001.

26. Miglino, O., H. H. Lund, M. Cardaci; *Robotics as an Educational Tool;* J. of Interactive Learning Research; V. 10, No. 1; 1999; pp. 25-47.

27. Nagchaudhuri, A., G. Singh, M. Kaur, and S. George; *LEGO Robotics Products Boost Student Creativity in Pre-College Programs at UMES;* presented at the 32nd ASEE/IEEE Frontiers in Education Conference; Session S4D; Nov. 6-9, 2002; Boston, MA.

28. Lund, H. H. and L. Pagliarini; *RoboCup Jr. with LEGO Mindstorms;* Proceedings of the 2000 IEEE International Conference on Robotics and Automation; San Franciscok, CA; April, 2000; pp. 813-819.

29. Bers, M. U., I. Ponte, C. Juelich, A. Viera and J. Schenker; *Teachers as Designers: Integrating Robotics in Early Childhood Education;* Information Technology in Childhood Education Annual; 2002; pp. 123-145.

30. Jackson, A. W. and G. A. Davis; *Turning Points 2000: Educating Adolescents in the 21st Century;* Teacher College Press; Williston, VT; 2000; p. 2.

31. Jeffers, A. T.; A. G. Safferman; and S. I. Safferman, *Understanding K-12 Engineering Outreach Programs;* J. Professional Issues in Engineering Education and Practice; April 2004, pp. 95-106.

32. S. H. Billig; *Research on K-12 School-Based Service-Learning: The Evidence Builds;* Phi Delta Kappan; May 2000; pp658-664.

33. K. Carr; *Building Bridges and Crossing Barriers: Using Service Learning to Overcome Cultural Barriers in Collaboration Between Science and Education Departments.;* School Science and Mathematics; V.102(6); October 2002; pp. 285-298.