Service-Learning Engineering Design Activities at Western Michigan University to Support K-12 STEM Education

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Abstract

The Engineering Design Center for Service-Learning (EDCSL) is a joint effort of the College of Engineering and Applied Sciences (CEAS) and the College of Education (COE) at Western Michigan University (WMU). The mission of the EDCSL is to provide instructional devices and equipment, experiments, and training for use in K-12 classrooms to enhance Science, Technology, Engineering and Mathematics (STEM) education. Engineering and education students, university faculty, and practicing K-12 teachers work together to design, build, analyze, and test age-appropriate classroom materials, develop and refine training for practicing and pre-service teachers, and provide opportunities for engineering and education students to see the impact of their work in the larger community beyond the campus boundaries.

This paper describes the ongoing EDCSL activities related to several of the student-engineered projects from CEAS senior capstone design courses and a freshman introductory engineering course. These include projects for a classroom playhouse; an apparatus illustrating Archimedes principle; an apparatus to teach and experiment on electromagnetism, which has been through several developmental iterations in the engineering design process involving students from CEAS, COE, and K-12 teacher customers; and an interactive wind tunnel. Materials developed during a joint workshop for practicing and pre-service K-12 teachers are discussed, where the participants worked with university faculty to develop their own STEM-related curriculum modules for classroom usage. Efforts continue to build and enhance a service-learning consortium with academic units within WMU, other educational institutions, and community groups, including a project with Goodwill Industries to design a shipping container that meets its operational and user requirements, and a project to deliver after-school enrichment activities based on engineering and technology for middle-school students.

Introduction

Western Michigan University (WMU) received project awards in July 2003 from the National Science Foundation and in October 2003 from Learn and Serve America to establish an Engineering Design Center for Service-Learning (EDCSL) as a joint effort between faculty members from the College of Engineering and Applied Sciences (CEAS) and the College of Education (COE). The activities of the EDCSL have focused on four main areas: (1) developing

and using STEM-related materials in several after-school enrichment programs; (2) incorporating service-learning design activities in senior capstone design courses; (3) development and implementation of a series of courses (ENGR 101, 202, 303, and 404) for institutionalizing service-learning design activities in the curriculum; and (4) developing and sponsoring a joint workshop for practicing and pre-service teachers. Ongoing activities in each of these areas are presented.

STEM-related Materials for K-12 Schools and After-school Programs

In Fall 2003, students enrolled in ENGR 101, "Introduction to Engineering & Technology," designed and built instructional devices to support hands-on learning of electromagnetism at Woodward Elementary School. ENGR 101 students initially engaged in laboratory exploratory "play" to learn about the electromagnetic phenomena. They then performed a web-based literature search to identify a design team's top three choices of activities for a design project and the associated science benchmarks, from which one activity would be selected for the team to design and build an instructional device to support the activity. The design specifications for the activity and instructional device included the following: must illustrate a set of concepts or one concept of electromagnetism in multiple ways; must allow students to collect data or to manipulate variables; be age appropriate; be safe to users; and cost less than $50 to build. One of the instructional devices created in Fall 2003 was Measure Mate, which is shown in Figure 1. Measure Mate consists of three solenoids with 150, 250, and 350 turns of 26-gage copper wire and powered by four 1.5 volt C-batteries. The strength of electromagnetism produced by the solenoid as a function of the number of turns of copper wire is given by the distance that the solenoid repels a permanent ring-magnet on a wooden dowel. A separate housing with the wooden dowel allows the ring magnet to slide from one solenoid to the others from left to right. The ENGR 101 students also created a manual on how to use Measure Mate.

In Spring 2004, Measure Mate and other instructional devices produced in Fall 2003 were tested by a group of pre-service education students enrolled in ED 401, a science methods course, and ED 402, another senior-level course typically taken the semester preceding student teaching. The pre-service education students found that, in general, the manual and device together usually made it clear what to do, and written directions were often easily followed; the desired effects that one should see were clearly stated and (less frequently) easily seen; and in most instances, science concepts were clearly explained. The education students also provided specific suggestions for improving the instructional devices.

In Fall 2004, students enrolled in ENGR 101 took the feedback from the pre-service education students and re-designed Measure Mate (Figure 2). One improvement consists of two power sources, 3 volts and 6 volts, to power the solenoids that can be selected by a toggle switch; this enables users to investigate the effects of number of turns of wire and current in the solenoid on electromagnetism. Other improvements include three ring magnets, one for each solenoid; use of push-button switches to activate the solenoids; and use of birch instead of plywood to improve the appearance of the apparatus.

The implementation sequence of design by ENGR 101 students, user testing by pre-service education students the following semester, and re-design of instructional devices by ENGR 101

students the following year will be adopted to create additional instructional devices to support hands-on learning of mathematics and science in K-12 schools.

Other STEM-related materials developed for a middle school after-school programs for the Spring 2005 semester include chemical and physical phase change[1, 2]; student designed and constructed solar-powered boats, which they can race against each other; basic computer programming; and design and construction of analog and digital electronic circuits on breadboards. Similar materials have been used by EDCSL volunteers at the local Boys and Girls Club, and a K-8 charter school, beginning in January 2004.

Senior Capstone Design Projects

Senior capstone design projects have included an optics demonstration and experimentation kit[3], a children's classroom playhouse[4], and a roller coaster to demonstrate Newton's Law of Motion and the Conservation of Energy. New projects include a preliminary design completed by a team of two high-school students from Kalamazoo Area Mathematics and Science Center (KAMSC) in Fall 2004 for an interactive wind tunnel to support the study of two science topics at Woodward Elementary School: aviation technology and aerospace. The wind tunnel will use a 2 horsepower blower to deliver a range of velocity from 0 to ~40 mph in the test section, which has a dimension of 8" x 8". A smoke generator will also be designed and built to provide flow visualization. It is expected that students from Woodward Elementary School will be able to investigate the effect of airfoil shapes on flow pattern as a function of wind speed. Furthermore, when the wind tunnel is constructed and characterized, Woodward teachers will be engaged to identify other experiments and/or design activities for their students. Redesign of the wind tunnel is expected for Fall 2005 by another team of KAMSC students based on initial testing at Woodward Elementary School in Spring 2005.

A current effort, to be completed in April 2005, involves a team of five senior engineering students working with the non-profit Goodwill Industries to redesign a shipping cart for handling donated items. The goals of this project are to evaluate the poor ergonomics and safety concerns of the current cart, explore multiple options for creating a cart that meets both human users' and corporate needs, and to create detailed design specifications for Goodwill Industries to use for a manufacturing process that provides employment opportunities for their clients. During this two-semester, community-based project, students interact constantly with supervisors, clients, and customers – a diverse community of individuals in terms of background, needs, and skills. Thus, this project provides not only a genuine engineering problem to be solved, but also rich opportunities for social interactions and growth seldom experienced in purely academic design projects.

Institutionalization of Service-Learning Activities

In addition to the ENGR 101 course, which has been taught each semester since Fall 2003 and which has a strong service-learning component, a major area of effort has been the development of a sequence of courses (ENGR 202, 303, and 404) in the engineering curriculum to support EDCSL activities, and to enable students to receive academic credit as engineering electives, or towards fulfilling the science requirement of education majors. These courses are being taught for the first time during the current Spring 2005 semester. The initial focus of the courses are for

teams of engineering and education undergraduate students to design, produce, and test STEM-related manipulatives and training materials. These are being developed in cooperation with practicing teachers, acting as clients, who will provide feedback for student teams to make further refinements and improvements. This iterative process is a true engineering design experience, and will allow a group of student designers to test manipulatives in a real-world setting and respond with improved versions. The ENGR 202, 303, and 404 course sequence provides a formalized structure for incorporating service-learning design activities within the engineering curriculum at WMU for the first time.

Joint Workshop for Practicing and Pre-service Teachers

A joint workshop for practicing and pre-service teachers to develop their own STEM-related materials for classroom usage was held in June 2004. Materials were developed for several topics areas, including, (1) using windmills and wind turbines to move objects, designed for middle-school students, (2) simple machines, designed for K-2 students, (3) using solar panels with different light sources and light source filters to generate electricity to operate simple electronic devices, such as a small fan or volt meter, designed for middle-school students, and (4) electrical circuit experiments for a high-school physics class. All topics were designed with multiple variables that students can manipulate, in order to be able to conduct experiments, rather than just following a scripted activity. The middle- and high-school level materials involve a data collection, data analysis, and report writing component.

Classroom testing for the simple machines and solar panels with varying light sources was conducted in November 2004, while the other topic areas are expected to be tested as part of classroom science activities in February 2005. Assessment of data and comments from the use in actual classroom settings is ongoing. For the materials tested in November 2004, changes and improvements have been identified, and it is anticipated that further refinement and testing will occur during the Spring 2005 semester.

Continuing to Build Community and University Partnerships

EDCSL continues to involve student volunteers from the university to carry out the after-school activities at the Boys and Girls Club, and the upcoming middle school program during Spring 2005. Additional opportunities are being sought with community groups, beyond Goodwill Industries. Discussions are also underway to partner with a local, private four-year university, which is primarily a liberal-arts institution, in order to provide STEM-related content to their student volunteers involved in K-12 outreach.

Acknowledgements

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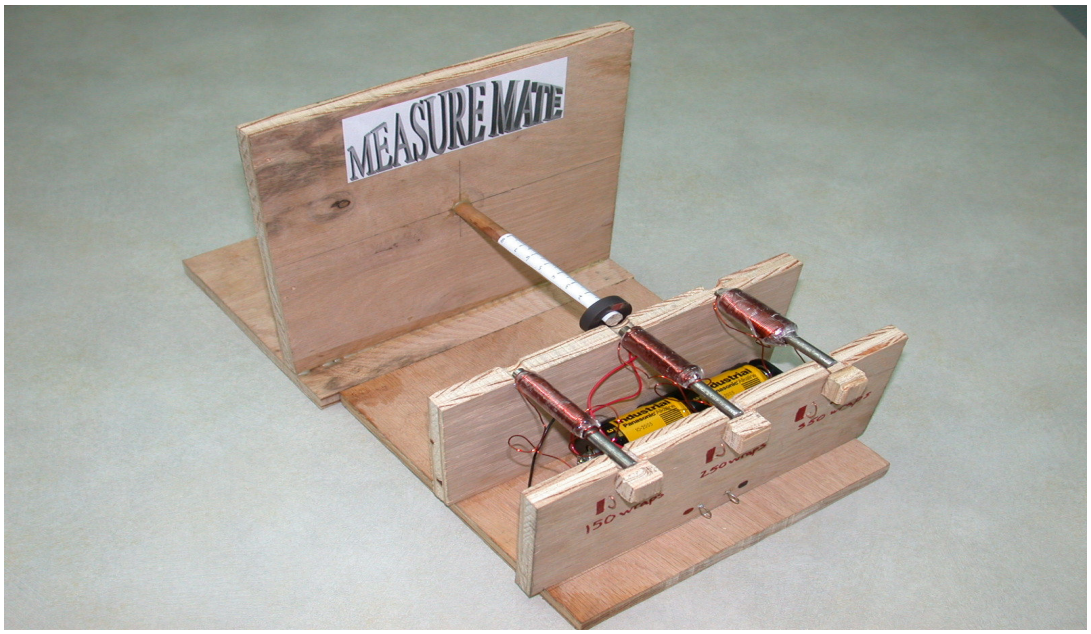

Figure 1. Measure Mate Designed and Built by ENGR 101 Students, Fall 2003.

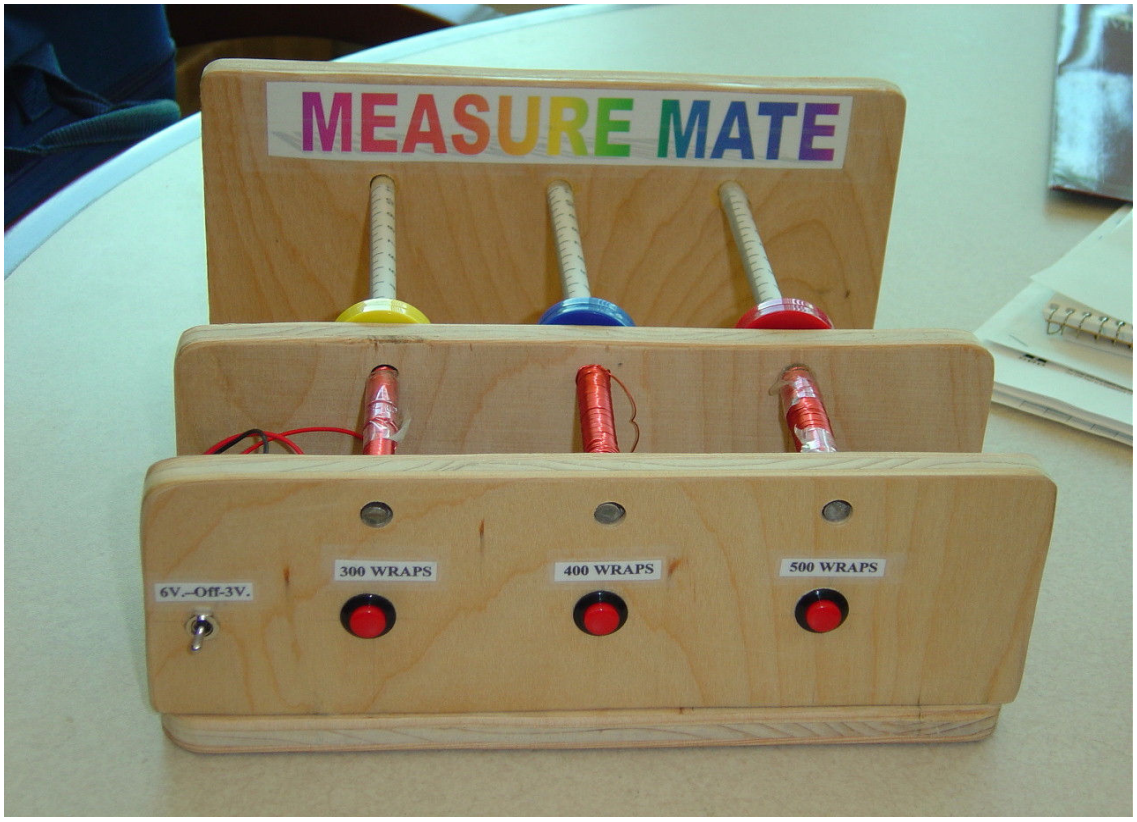

Figure 2. Improved Measure Mate Designed and Built by ENGR 101 Students, Fall 2004.

Biographical Information

ANDREW KLINE is an Asst. Professor of Chemical Engineering, and joined the WMU faculty in 2001after a post-doctoral appointment at Cornell University. He is the director of the Engineering Design Center for Service-Learning; teaches the chemical engineering senior capstone design sequence; coordinates the ENGR 202, 303, and 404 courses; and includes aspects of the engineering design process in his freshman and sophomore-level courses.

EDMUND TSANG joined WMU in 2001, and is the Associate Dean for Undergraduate Education and Assessment within the College of Engineering and Applied Sciences (CEAS). He was previously faculty at the U. of Alabama for over 20 years, and is well-known in the ASEE and FIE communities for his service-learning expertise. He currently teaches the ENGR 101 course, and classes in the Mechanical and Aeronautical Engineering department.

BETSY M. ALLER is an Asst. Professor of Industrial and Manufacturing Engineering (IME), and joined the WMU faculty in 2001. She previously held faculty appointments in the Engineering Communication Program at Cornell University, and at Michigan Technological University. She teaches the IME senior capstone design sequence, freshman- and junior-level engineering communication courses, and contributes to ENGR 101, 202, 303, and 404.