AC 2010-209: POSTER: THE SYSTEMS AND GLOBAL ENGINEERING PROJECT

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Poster: The Systems and Global Engineering Project

Abstract

Systems engineering is a rapidly growing field that addresses the need for multiple entities to collaborate on the development and operation of complex products and systems. Stevens Institute of Technology and the New Jersey Technology Education Association have partnered to develop, pilot and disseminate systems and global engineering instructional modules for use in high school engineering, technology and science courses. This paper/poster provides an overview of the Systems and Global Engineering (SAGE) project including a description of the instructional modules and results of teacher surveys and pre-and post-tests administered to students who participated in the Introduction to Core Concepts of Systems Engineering module.

The SAGE Project

Engineering is increasingly conducted in a global environment that requires multiple entities to collaborate on the development and operation of complex products and systems. Systems engineering is a rapidly growing field that addresses this need. Stevens Institute of Technology and the New Jersey Technology Education Association (NJTEA) have partnered to develop, pilot and disseminate systems and global engineering instructional modules for use in high school engineering, technology and science courses.

During the early spring of 2008, the project staff, working together with faculty from the School of Systems Enterprises identified the specific systems engineering concepts and types of activities which could engage students in mastering these concepts. As Systems Engineering is a relatively new disciplinary field of academic study, our working group has been able to draw upon the expertise of several Stevens faculty members who have written textbooks and are conducting research on systems engineering concept learning. During this planning phase, it was determined that students should:

- Learn about and experience systems engineering concepts and practice
- Engage in a geographically-distributed design experience that has a hands-on technological design activity
- Where possible, make use of CAD software such as Pro/Engineer

An application process was used to select six lead teachers who would develop instructional modules for use in New Jersey and, eventually, throughout the U.S. and internationally. NJTEA members were recruited to become lead teachers. Interested teachers submitted applications and six teacher-leaders were chosen. Lead teachers received a stipend for a scope of work that included several meetings with project staff at Stevens Institute of Technology, development of content specific modules, teaching during the summer institute and continued assistance in refining the modules. During the spring and early summer the six lead teachers from worked in

teams with project staff and systems engineering faculty to develop instructional modules focusing on global sustainability.

Each module is designed to engage students in developing innovative solutions to problems of global significance. In the **Biodynamic Farming** module students are challenged to design and operate a system as a model for use in developing countries. The module combines hydroponics (growing plants without soil) and aquaculture (fish farming) to produce food. The **Home Lighting** module is based upon the integration of LED and solar technologies to produce safe and cost effective lighting for use in homes that do not have access to the electric grid. More than 2 billion people do not have access to clean drinking water. Students participating in the **Water Purification** module will develop an understanding of this problem and be challenged to develop model systems to meet the needs of people in specific communities.

The project team developed the **Introduction to Core Concepts of Systems Engineering** module which is used in all participating schools prior to the content specific modules described above. Students learn about systems and systems engineering as they reverse-engineer a common device that contains both electrical and mechanical components. Schools exchange reassembly instructions and diagrams and attempt to reconstruct the device.

One of the unique aspects of the SAGE project is how students use Collaboration Central to work with students from other schools. Collaboration Central is an online communication tool and an integral part of each of the instructional modules. It encourages use of the engineering design process as students discuss their projects and enables them to exchange photos, videos and drawings to facilitate shared decision-making. In the Introduction to Systems Engineering module students swap reassembly instructions for a product such as a single-use camera. The Home Lighting module challenges students to form design, build and marketing teams and exchange information with corresponding teams in other schools. More advanced approaches to long distance collaboration are used in the Water Purification and Biodynamic Farming modules.

During the spring of 2008, the process for selecting pilot teachers was developed. The pilot teacher application detailed obligations which included submitting a letter of interest and a letter of support from an administrator, attendance at the four-day summer institute, module implementation and allowing classroom visits from Stevens staff members. The selected pilot teachers received a stipend for participating and up to $1,000.00 in classroom supplies to implement the modules. Eighteen pilot teachers and six lead teachers participated in the August 4-7, 2008 professional development workshop. The week started with a detailed overview of systems engineering by Dr. Eirik Hole, professor of systems engineering. A discussion about the goals of the project followed, and then teachers participated in the introductory systems engineering activity, to reverse engineer single-use cameras.

Laptop computers were available to each teacher during the workshop, and teachers were guided through the project web site. The teachers also used the laptops to work on their implementation plans and to provide feedback through pre- and post-workshop surveys. More than 70% of the pilot teachers stated that each of the four modules was very valuable and all of the teachers stated

that the overview of systems engineering was very valuable. An efficacy scale showed that teachers' level of confidence increased in the areas of content knowledge, telecollaboration techniques and engineering. The teachers reported that the SAGE web site was well organized and easy to navigate. Teachers also reported that the most valuable part of the workshop was the detailed overview of systems engineering.

During the past year all of the instructional modules --Introduction to the Core Concepts of Systems Engineering, Home Lighting for Developing Countries, Biodynamic Farming and Water Purification --were pilot tested. The Stevens project team facilitated implementation of the modules through online interaction with teachers and students and through classroom visits to observe and assist. An asynchronous online discussion forum, Collaboration Central, provided the primary means for student collaboration during the pilot test. Different types of documents, files, images, photos, sound and video recordings, and links were uploaded to Collaboration Central. Students initially shared Letters of Introduction which served to describe their school and geographic location as well as the goals and expectations they may have had for the project. Classes later used Collaboration Central to post specification and requirements documents, design drawings, procedures, and test results. The instructional modules including examples of student work can be viewed at www.stevens.edu/ciese/sage .

The Core Concepts module has been offered three times this past year and has been enhanced to include a special advanced reverse engineering activity as a result of teacher and student interest. Eight schools participated in the pilot test of the enhanced module which required schools to work in pairs and collaborate to select a product to reverse engineer. In addition to NJTEA members, teachers from New York, South Carolina and Florida participated in the online collaborative projects. Evaluation of the project is ongoing and primarily of a formative nature at present. Both quantitative and qualitative data are being collected to evaluate and inform revisions of various aspects of the project as well as to measure student learning as a result of completing the curriculum modules.

Twenty-four teachers committed to implementing the introductory module in the fall of the 2008-09 academic year. One of these teachers rescheduled classroom implementation to the spring semester. Of the remaining 23 teachers, 16 implemented the module in widely varying degrees. Teachers were requested to administer pre-and post-tests to their students and to respond to a brief online survey after completion of the module. Twelve teachers returned answer sheets for both the pre- and post-tests for their students. Thirteen teachers completed the online survey. The following sections refer to the data collected from these teachers and their students.

An assessment to measure student knowledge of and ability to apply systems engineering concepts was developed internally. While use of items from existing assessments with established validity is desirable, a lack of existing courses and assessments for systems engineering at the high school level necessitated development of an assessment for this module. The project director and an individual with substantial experience in assessment development worked collaboratively to create the assessment, which was then reviewed by two systems

engineering faculty members. Revisions to the assessment were made based on reviewers' recommendations.

Teachers administered the assessment prior to implementing the module in their classes and again at the conclusion of the module. The gains or difference between pre-and post-test scores serve as an indication regarding high school students' ability to comprehend and apply systems engineering concepts. Twelve of the 16 teachers who implemented the module returned pre-and post-tests for a total of 327 students. Of these, both pre- and post-tests were received for 271 students. Results from the paired t-test demonstrate that students had significant gains overall and specifically in the recall of systems engineering concepts and their application. Teachers were requested to complete an online survey after implementing the module in their classes. Thirteen teachers completed the online survey, which provided feedback regarding their experiences with the module and additional information used in interpreting the results from the student assessments.

The results from the student assessment and completed teacher surveys from this pilot implementation of the SAGE introductory module demonstrate that systems engineering concepts and activities are both appropriate and desirable for high school level courses in technology, engineering, and science. Significant student gains on the assessment indicate that high school students can comprehend and apply systems engineering concepts. Teacher responses demonstrate an interest in incorporating these concepts and activities on a continuing basis as12 of the 13 teachers responding to the survey reported that they were either very likely (8) or somewhat likely (4) to use this module again. Previous ASEE papers have shared detailed findings on teacher impact and student learning.[1, 2]

Five online short courses have been developed to provide teachers with the background knowledge needed to insure successful implementation of the instructional modules and to increase their experience in online collaboration. The courses deliver content through readings, videos and interactive assignments. Participating teachers engage in discussions that focus on strategies for implementing the modules within their classrooms and in collaboration with other schools. Three of the short courses; Core Concepts of Systems Engineering, Reverse Engineering and Home Lighting for Developing Countries were piloted in November and December of 2009. Feedback from the lead teachers who have completed the short courses in preparation for serving as instructors, will be used to refine the courses prior to offering them to the general teacher population. Two additional online short courses will be piloted in 2010.

By the end of the project, it is estimated that 700 teachers in New Jersey and across the U.S., as well as internationally, will have learned about the Systems and Global Engineering modules and that at least 100 schools will be involved in an extended, intensive Systems and Global Engineering project.

Bibliography

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