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The Systems and Global Engineering Project

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Imagine having your students collaborate with others from around the world to model solutions to some of today's most significant global problems. That's the goal of the Systems and Global Engineering (SAGE) project. Stevens Institute of Technology and the New Jersey Technology Education Association (NJTEA) have teamed up to develop innovative instructional materials during the three-year SAGE project.

During the spring and early summer of 2008, Stevens faculty and staff worked with six NJTEA lead teachers 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 that 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 two billion people do not have access to clean drinking water. Students participating in the **Water Purification** module develop an understanding of this problem and are challenged to develop model systems to meet the needs of people in specific communities.

One additional module, **Introduction to Core Concepts of Systems Engineering,** was developed and designed to be used by all participating schools prior to the content-specific modules described above. In this module, students learn about systems and systems engineering as they reverse-engineer a common device such as a single-use camera that contains both electrical and mechanical components. Schools electronically swap reassembly instructions and diagrams and attempt to reconstruct the device.

In August of 2008, twenty pilot teachers attended a four-day workshop. All received an introduction to systems and global engineering from Stevens faculty, as well as an overview of each module. Then they spent two days learning how to implement one module within their own classroom and in collaboration with other schools. Pilot teachers used the Introduction to Core Concepts of Systems Engineering module in their classes during the fall of 2008 and then implemented one additional module during the spring of 2009.

Collaboration Models

Many aspects of the projects featured within the four project modules may seem familiar to technology educators. Yet, what makes this endeavor more unique is how students end up working together with students from other schools. Four paradigms have emerged as collaborative models for students to work with others through the course of the projects. Each of the four modules reflects one of these four different models for student collaboration: Sharing, Mentorship, Workflow, and Interdependent Subsystems.

Sharing

The "Introduction to the Core Concepts" module provides an opportunity for students to share their work and outcomes with other classes and schools. While the level of interaction can be considered relatively low as students generate most of the work for the module independently, the students do rely on the information provided by other schools to continue at certain points of the project. Students post to message boards and share files as they orient themselves to "Collaboration Central," a web-based system designed to facilitate communication between students and schools.

Mentorship

As the students work through the "Water Purification" module, they use collaboration more as a resource for information. The thought is that schools and teachers that may participate in this module year-to-year would become mentors to new classes that want to engage in the project. Students will eventually be able to post questions and experiences and have more experienced teams of students respond to inquiries. The mentorship model of collaboration becomes beneficial to all students. Those who have less experience benefit from the information provided by peers and student mentors, which may lead to better long-term retention.

Workflow

A workflow-type process is employed in the "Home Lighting" module as different groups of students work on different aspects of the project in a more linear fashion. Different student teams are responsible for design, modeling, production, and marketing, and the idea is that each team passes its work on to the next team for the next stage in the logical development of the project. This sort of model is used naturally and quite often in business and industry; each stage of development is reliant on others. This requires a high level of student interaction throughout the project, but does not necessarily require certain teams to wait for other work to be complete. Again comparing this work to the way business takes place, planning for marketing of a product may take place long before the final product is developed.

Interdependent Subsystems

This model of student collaboration is perhaps truest to a systems engineering model of technological development. Just as with the design, development, and production of a very complex device such as a jetliner, students in the "Biodynamic Farming" module develop subsystems of a larger system that need to work with and fit together with other items in the larger system. Student leaders, facilitators, and orchestrators must emerge through the project—all roles that are akin to those of a systems engineer. Students who participate in this module are interacting in a way that 21st Century careers will require, as they will likely have to rely on information and contributions of others for their success.

To work in the ways described above undoubtedly presents a number of challenges to the typical classroom and school schedules. One of the main goals of the SAGE project is to facilitate the expected challenges and provide support for the unexpected. Ultimately, the hope is that students will work both synchronously and asynchronously in some fashion with students from across the globe. "Collaboration Central" has been designed to help make the collaborative aspects of the project easier by providing a repository for information, questions, files, and other resources directly available to the teacher and students.

Classroom Implementation

One technology education teacher describes how he implemented the project in collaboration with students from six other New Jersey high schools. Over the course of the six-week Home Lighting in Developing Countries module, I was able to witness students collaborating on levels that I had never seen before. The students enjoyed reading and reacting to the daily updates on the Collaboration Central web forum, and working with other schools pushed them to produce work that was clear and to the best of their abilities. As with any project that is being run for the first time, it was not without its hiccups and required flexibility from both students and teachers. Fortunately, the small issues were worked around, and the fact that there were six other schools involved meant that the project as a whole was able to continue on schedule.

By the end of the project it became obvious that the students gained an understanding of how important it is to produce documents and ideas that are clear when dealing with people in remote locations. Whether it was a paragraph written to communicate an idea or design concept, or a CAD rendering done in SketchUp, through the course of the project their work became more clear, concise, and descriptive of their intent. Another positive aspect that surfaced as the project progressed was the students' firsthand knowledge of the "real-world" workings and relationships of designers, marketing teams, engineers, and manufacturers.

The project's workflow was consistent throughout. Typically, the class would read and discuss the week's goals, then split into specific groups to come up with ideas and documents. Every student came up with ideas of his or her own, which the group then sifted through, voted on, and reworked. The group then presented the class with its three final ideas. The class as a whole would then discuss and vote on which of the three would be posted to Collaboration Central for the other schools to review. We asked questions and critiqued other schools' work, just as our own work was being critiqued. Threads would be started to which every school would post votes to determine which concept should move forward and be further developed. This is a great framework because, even if a school cannot participate in one section of the project due to a lack of space, equipment, or software, they can contribute in other sections. They will gain the satisfaction and learning experience associated with contributing to the project and also learn from watching the development of other sections.

For most of the project, my class was broken up into three groups. The Marketing and Advertising (M&A) group, the Industrial Design (ID) group, and the Electrical Engineering (EE) group. The M&A group was in charge of brand identity. This included company name and logo, letterhead, business cards for every student, and all educational, advertising, and packaging materials. The ID group was in charge of the form and function of the product. They produced design sketches, computer renderings, and initial prototypes. The EE group was assigned with finding the best arrangement of solar cells, LEDs, and rechargeable batteries to meet the project's requirements. The EEs produced working circuits for charging and lighting, reflectors for the LEDs, and schematic diagrams to post on Collaboration Central. With such a wide scope of tasks available and deliverables needed, students were able to find something they were comfortable doing and then enthusiastically contribute ideas and solutions to the project.

One of the most important parts of the project was coming up with a System Requirements Document. This list of requirements was the guiding voice for all aspects of the project. We worked as a class to brainstorm ideas regarding product inputs and outputs. We discussed the product's operating environment and what that meant in terms of materials and design. Our target market was considered and factored into this document. As with all phases of the project, the Systems Requirements Document went through several revisions as all the schools contributed to and reworked the document into its final form. Students were surprised, as every school brought new, valid ideas to the table, and the value of collaboration was experienced firsthand. Some other aspects of the project that we designed, critiqued, voted on, and posted were company name and logo, final form of the product, and final circuit design.

The successful implementation of the project hinged greatly on a continued exchange of constructive criticism in the online forum. This project format allowed students to see and compare many ideas about one problem. Encouraging my students to explore and question other groups' ideas proved to be a very powerful way to improve their own ideas, designs, and solutions. And this worked both ways. When students read comments and answered questions posted about their own ideas, they began to increase their objectivity and see the importance of considering all aspects when designing solutions.

Throughout the project some typical student habits required management. For example, it was difficult to direct students away from the habit of voting for their own ideas. Again and again we would see this trend from most classes. In order to promote more objective voting, I discussed with the class the pros and cons of each idea as related to the systems requirements document. By doing this, I was able to distance the students from their own ideas and their desire to "win," giving them a structure from which to make an informed, logical vote.

In Summary

The SAGE Project has demonstrated how students can use collaborative problem solving to address the challenges facing today's society and environment. Students learn a variety of skills used by technologists and engineers to identify problems, determine possible solutions, test and select the best solutions, reach conclusions, and make recommendations for further study.

During the 2009-10 school year, teachers in New Jersey and across the U.S., as well as internationally, have been invited to participate in this intensive systems and global engineering project. To learn more, please visit the project website, www.stevens.edu/ciese/sage.

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