The Effect of Engineering Design Activities on Student Learning and Attitudes in Secondary High School Science Classes

Purpose of the Study

With the rapid increase of foreign competition for engineering and technology-related jobs, there is a strong need for a technologically savvy and broadly educated workforce in our country. Since these technology-related jobs are the driving force behind economic growth, our economic future depends on our ability to educate our children in science, technology, engineering, and mathematics (Kumagai & Hood, 2005). Thus, methods for enhancing student learning and attitudes in these areas are of great importance to the public interest.

This study was developed to investigate the effect of hands-on engineering design activities on student learning in high school science classes. These activities are built on the active learning model, involving a specific problem that is given to the students to solve through the use of engineering design principles. The design problem is centered on concepts the students learned in their classes, thus addressing specific educational standards. Our hypothesis is that the design activity will enhance student learning and attitudes toward science and engineering.

Theoretical Framework

Recent research espouses active learning in the areas of science and mathematics. Lessons that use active learning emphasize making sense of a concept, using the newly created knowledge or schema in an attempt to complete a task, and self-assessing the results to make adjustments and improvements. These practices have been shown to improve student comprehension (White & Frederiksen, 1998; Schoenfeld, 1991) and ability to transfer their learning from one setting to another (Palincsar & Brown, 1984). By providing students the opportunity to take control of the activity, the learning becomes more important and meaningful to the student (Bransford, Brown, & Cocking, 2000). Therefore, an increase in student learning and attitudes toward science and engineering may be measured after the completion of an engineering design activity that incorporates active learning.

Research Methodology

The research was conducted in an urban secondary school located in a mid-sized Midwestern city. Fifty-three 9^{th} grade students in a Physical Science class and twenty-four 12^{th} grade students in a Physics classes were included in the study. The students who participated in the study were from a population that is at least a 90% African American from a low socioeconomic background; the students were approximately half males and half females.

The Physical Science class met six times for a period of 50 minutes. The lesson "Boat Float Challenge" engages students through the task of designing a boat using a limited set of materials. Students work in groups of two to achieve several design goals, which culminates with the Boat Float Challenge competition. Each design is tested and awarded points for the following categories: (1) Distance traveled with one blow; (2) Amount of weight it can hold; and (3) Cost efficiency. This activity includes checkpoints in which students have the teacher review their work after completing specific tasks throughout the lesson. This shows incremental student work and also allows the teacher to keep all students moving at the desired pace.

In the Physics lesson students met twice, for a total of three hours. The students are given the task of designing a vehicle that is powered by an air-filled balloon. Their goal is to have their vehicle go the farthest while also maximizing their cost efficiency. Students work in groups of two and must use a limited set of materials that have been assigned fixed costs. A competition is held to determine the vehicle that went the farthest, the most creative design, and the top overall (cost effective and distance).

The complete lessons are available at the website http://www.eng.uc.edu/STEP, and include lesson plans, handouts, competition guidelines, pre/post tests with answer keys, an introductory Power Point, detailed results, instructor reflections, examples of student work and photos.

Two instruments, both paper-and-pencil objective tests, were used to measure the variables of cognitive achievement and attitude toward learning. For each class, a pre-test was administered to the students to assess their prior understanding of the concepts included in the lesson. The same test was administered following the lesson to determine whether learning took place. Additionally, a survey was given to the students after the lesson to determine the effect the lesson had on their attitudes toward science and engineering.

Findings

Both descriptive and inferential statistics were calculated with all assumptions of the inferential testing met. The expectation that there would be a significant difference between achievement and attitude toward learning was met.

In comparing the results from pre- and post-tests, statistically significant increases in average scores were seen in both classes on the post-test. The class average on the Physical Science pre-test was 23%, which increased to 61% on the post-test ($t = 11.24$, $p = .000$). Similar results were observed in the Physics classes, which saw an increase from 56% to 78% ($t = 3.60$, $p = .002$).

Additionally, the student feedback survey showed a marked effect on student attitudes. Many students reported an increase in their interest in engineering (58% and 36% in Physical Science and Physics respectively) and the majority of students reported that they felt more confident in their ability to learn science (83% and 80% in Physical Science and Physics respectively).

Anecdotal evidence support these achievement and attitude findings. Informal student reflections indicated that students really enjoy learning in this way. They made comments such as “I liked how we got to work at something, making a design of our own" and "I like that it gave us a chance to explore the engineering world."

Significance of the study

While there is agreement that the field of engineering design has strong potential for the education of secondary science students, little research has been conducted to validate its full range of possibilities for enhancing cognition and attitudes towards learning. The results of this study show that hands-on engineering design activities have a positive impact on student learning and attitudes toward science and engineering. These activities are relatively inexpensive and easy to implement in science classes at all levels of secondary education. Additionally, these engineering design activities can be tailored to enhance the study of numerous scientific concepts while incorporating the appropriate education standards.

References

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