Introduction

It is a well-known fact that the majority of pre-college students have insufficient background in mathematics and science for attending engineering colleges. In the past two years, various measures have been developed to make the two subjects more appealing to secondary school students. However, to strengthen the pipeline between pre-college students and engineering schools, more attention should be focused on pre-secondary education because students’ attitude toward science and mathematics become fairly well established at the age of 10 to 14 (the middle school years).

Our survey on current status of middle school education reveals the following three problems: 1) many middle school teachers in mathematics and science are inadequately trained. 2) subject matters in these two areas are being taught with inadequate coverage on the application of basic theories. 3) while teachers prefer to use a learner active, hands-on form of education, their content background makes this very difficult. The combination of these three problems has an adverse impact on students’ interest in these two subjects.

One promising way to deal with these problems is to introduce engineering topics into the pre-secondary curricula. Through engineering topics, students can appreciate how mathematics and science principles are used to solve problems closely related to their life and daily experience. This approach not only would allow them to learn basic science and mathematics in an exciting way, but also would change their perception that these subjects are uninteresting and irrelevant. Moreover, exposing students to open-ended engineering problems also provides the best avenue to nurture students’ abilities in problem-solving, teamwork, and creativity.

Recognizing the significant role engineering can play in middle school education, we secured an Eisenhower Grant to develop a 1999 Summer Workshop "Adventure into the Mechanical World" at the University of Wisconsin-Platteville for middle school teachers.
Objectives of the Workshop

The primary objective of the workshop is to develop and implement an application-oriented pedagogical approach to support pre-secondary mathematics and science education. The specific objectives are:

- to offer teachers a framework for developing problem solving skills required, such as critical thinking, communication, analysis, and teamwork,
- to deepen and enrich teachers’ understanding of mathematics and science subjects,
- to introduce active teaching and learning methods to pre-secondary classrooms,
- to assist teachers in developing education materials for inquiry-based learning,
- to develop partnerships with middle schools in Southwestern Wisconsin to increase students’ awareness and interest in engineering.

Organization of the Workshop

The workshop was conducted at the University of Wisconsin-Platteville in June of 1999 and offered a total of sixteen five-hour sessions over four weeks. The first three weeks focused on engineering topics while the fourth week was devoted to action research where teachers developed instructional materials for use in their classes. Although no stipend was paid to the participating teachers, they received four graduate credits towards a master’s degree in education and did not pay tuition. Faculty from engineering and education disciplines served as instructors for the workshop and were responsible for developing course materials, demonstrations, and laboratory experiments. They also served as consultants in engineering design activities. Topics covered in the workshop are mostly in the field of mechanical engineering because mechanical systems are closely related to concepts of mechanics, energy, and structures.

We adopted the inquiry-based learning style that relied heavily on active participation and hands-on activity to implement collaborative learning throughout the entire workshop. Participants were organized into teams of four to conduct discussions, laboratory work, and engineering design. Daily activities included the following three components:

- Lecture and discussion - The purpose was to reinforce concepts in mathematics and science, and to lay the groundwork for laboratory and design activities planned for that day. Typically, the lecture and discussion would last less than one hour.

- Laboratory work - A number of simple and inexpensive home-built devices and toys were provided to teachers to illustrate science and mathematics principles and to provide teachers with a set of useful teaching tools for use in their classrooms.

- Design - It was a project-based learning experience in which teachers learned
engineering problem techniques in conjunction with mathematics and science knowledge to solve real world problems.

Educational Activities

The workshop covered the following topics:

1) Introduction to Engineering. Participants toured engineering facilities and were made aware of different branches of engineering. It also included an introduction to engineering problem solving techniques. Teachers learned how to use a decision matrix to make engineering decisions.

2) The Science of Playgrounds. This topic covered the law of motion, the concept of force, and the condition for equilibrium. Laboratory work included experiments with a seesaw (for rotational equilibrium), slides (for frictional force and inertia), swings (for pendulum), tension and compression forces, and equilibrium of forces\(^1\). Participants then used this knowledge to examine the safety features in passenger compartments of automobiles.

3) Simple Machines. Five types of simple machines, such as levers, wheel and axial, pulleys, wedge, and screws, were used to illustrate the concept of mechanical advantage and the relationship among work, energy, and power. Laboratory work included several experiments\(^2\) and the mechanical advantage in a finger nail clipper. Participants were then provided with ropes, taps, and newspaper to devise a method to transport eggs across a gap of fifteen feet.

4) Anatomy of Bicycles. Participants first identified how a bicycle is built from a combination of simple machines. They then studied the mechanical advantage in the braking and power transmission systems. In the laboratory work, they first predicted the rotational speed ratio under various combinations of gear ratios and then verified their prediction experimentally. In the design activity, participants analyzed the stability problem in braking a bicycle and identified relevant design parameters.

5) Wonderful World of Gears. The main objective was to demonstrate the application of mathematical operations in gear train design. Laboratory work included the assembly of a gear box from a commercial kit. Teachers were then given a set of plastic gear to design a gear train with a certain speed ratio under the constraint of a given volume.

6) Airplanes. This topic covered the concept of fluid pressure and Bernoulli’s principle. Several experiments\(^3\) were conducted. Teachers were then asked to make paper planes and participated in a paper plane contest.

7) Amusement Park Roller Coaster. This activity was to introduce the concept of kinetic and potential energy and the conservation of mechanical energy principle. Several types of roller coaster toys were provided for teachers to study the potential energy in gravitational fields and in elastic springs, and the energy loss due to friction. In the design activity, teachers worked on a theoretical model for bungee jump.
8) Design a Bungee Jump. Teachers were asked to design and make a bungee cord from rubber bands that allowed a bungee jumper (a barbie doll in this case) to come as close to the ground as possible (without hitting the ground, of course) after it was released from a given height (10 feet in our case). The task included developing a simplified mathematical model, selection of the rubber bands, measuring the elasticity of the bands, and design a cord length. They then put their design to test and see whether their mathematical analysis was valid or not.

9) Catapult Studies. This activity served as a summary to the study of mechanical world. Each team of teachers was provided a home-built catapult whose geometrical configuration can easily be varied. Teachers would apply the basic principles to identify parameters that would affect the distance of throw from that catapult. This was followed by experiments to check whether their prediction was correct or not.

10) Physics and Engineering of Structures. The objectives were: (1) to reinforce the concepts of forces, torque, center of mass, and equilibrium covered previously; (2) to introduce the concept of stability and trusses. A design contest was then held. Each team was provided with 20 straws and 20 pins to build the tallest tower that would hold an egg at the top.

11) Building Bridges with Computer Software. A software program "West Point Bridge Designer" was introduced to the teachers. After learning how to use the program, the teachers also explored the use of the program in their classrooms.

Lessons Learned

The enthusiastic support from the workshop participants affirms the strength of our approach. We believe the following factors are the keys to the success of the workshop:

1) Address the needs of the teachers. Teachers were mostly interested in materials that they could use in their classrooms. They preferred not to deal with challenging problems such as the design of an elastic cord for bungee jumping. Once the problem was discovered, we adjusted the level of presentation and made sure that the materials would benefit the teachers.

2) Show various facets of a subject. Since backgrounds and interest of participating teachers vary, the material should cover many facets of a subject. For example, in studying the subject of airplanes, we also introduced the history of flight. This would provide flexibility to teachers so that they could choose a suitable aspect of a subject for use in their own teaching.

3) Emphasize collaborative learning. It is a challenge to cover a subject to a group of teachers with diverse backgrounds in mathematics and science. We found that team learning provided an environment conducive to learning and was very effective.

4) Emphasize hands-on approach. The teachers were most excited about hands-on activities and design, where they learned by exploring and discoveries.
Closure

The 1999 Workshop "Adventure into the Mechanical World" has successfully introduced engineering to middle school teachers. Participants felt that the principles of engineering and technology were well presented and were very useful. All participants were eager to use the knowledge they learned in the workshop in their classroom. They also agreed that the inquiry-based learning was the best way to introduce science, mathematics, and engineering to students.

Bibliography


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Biography

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