2006-1201: HOW DO YOU TEACH ENGINEERING IN GRADES K AND ONE?

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How do you Teach Engineering in Kindergarten and First Grade?

Abstract

As part of the National Science Foundation (NSF)-funded program titled "K-6 Gets a Piece of the PIEE (Partnerships Implementing Engineering Education)," graduate fellows and undergraduate students at Worcester Polytechnic Institute (WPI), Worcester, MA have implemented a technology and engineering curriculum in kindergarten and grade one in the Worcester Public Schools (WPS) System. This follows successful implementation of the technology and engineering curriculum in the first two years of the program in grades two through six. This project is also part of the NSF Graduate Teaching Fellows in K-12 Education (GK-12) program, the goal of which is to involve engineering graduate students with K-12 science and engineering education. Massachusetts is one of the few states to have mandated the teaching of engineering and technology topics from kindergarten through grade twelve.

Needless to say, the approach to teaching engineering that is suitable for the university, high school, middle school, or fifth and six grade levels is unworkable in kindergarten and first grade. For example, the students cannot read or write! Nevertheless, concepts such as creative design, materials selection, and proper tool use can be effectively taught if approached in the appropriate way. Graduate fellows have written and illustrated a set of picture books that provides a particularly effective introduction to these topics. Curriculum plans, representative lessons, program successes, and lessons learned, are described below.

Introduction

This project, titled Partnerships Implementing Engineering Education (PIEE), is part of the NSF Graduate Teaching Fellows in K-12 Education (GK-12) program, the goal of which is to involve engineering graduate students with K-12 science and engineering education. Massachusetts is one of the few states to have mandated the teaching of engineering and technology topics from kindergarten through grade twelve.

The PIEE project team at WPI consists of two principal investigators, three faculty/staff members, six graduate fellows, and fourteen undergraduate students. In the Worcester Public Schools (WPS), it consists of three principals, twenty seven teachers, and over four hundred elementary school students. More specifically, the kindergarten and grade one team is staffed by one WPI faculty member, two graduate students, four undergraduate students, and four elementary school teachers. More than eighty kindergarten and first grade students participate. Principal investigators oversee the project as a whole, manage teams at each grade level, and coordinate WPI/WPS relations. Other members of the WPI faculty and staff advise undergraduate students as they complete their service learning projects and provide support to graduate fellows. Graduate fellows devote full time in the summer and half time in the academic year to their K-6 activities, which include substantial time in the elementary classrooms and with elementary school teachers as they design and often deliver units, lessons, and lesson materials on engineering topics. In addition, the fellows work closely with undergraduate

students and assist in advising undergraduate projects. Undergraduate, mostly third year, students assist in all activities as part of their required service learning project. They provide expertise in Technology/Engineering, assist in lesson plan creation, and write year end reports describing in detail their work.

The PIEE project began in the fall of 2003; the program, "K-6 Gets a Piece of the PIEE (Partnerships Implementing Engineering Education)," is over three quarters complete and will finish in June of 2006. The final product is to be seven complete curriculum sets (K-6) designed to mesh with the current science curriculum while meeting the Technology/Engineering standards set forth by the state of Massachusetts. This complete curriculum will be available in June of 2006 at http://www.wpi.edu/Academics/PIEE/.

Background

Engineering in Kindergarten and First Grade

The Technology/Engineering standards set by the state of Massachusetts for kindergarten and first grade students focus on two areas: "Materials and Tools" and "Engineering Design".[1] Since these topics are absolutely fundamental to higher-level engineering, the Massachusetts Department of Education requires that basic concepts behind materials, tools, and engineering design be taught at an early age. These concepts include: characteristics/uses of natural and manmade materials; uses of simple tools such as rulers and scissors; uses of simple machines, such as levers and pulleys; and the ways in which animals use body parts as tools, as in the case of tails and beaks. PIEE graduate fellows and undergraduate students created a set of lesson plans and lesson materials that elementary school teachers may use to teach Technology/Engineering and meet the aforementioned standards.

Learning Characteristics

Behavioral and learning characteristics of kindergarten and first grade students differ from those of older elementary students. While fourth, fifth, and sixth grade students can quietly read a story and respond to the material, most kindergarten students are highly energetic, cannot read, and cannot write; first grade students have only basic reading and writing skills and are nearly as active. The relatively short attention spans of young students require that activities change every ten to fifteen minutes and that hands-on individual activities rather than team-based activities, be incorporated into each lesson.[2] Repetition and discussion are also important aspects in designing lesson plans for this age group, and are necessary for the students to retain presented information.

Past Efforts at Teaching Engineering to Children

Price[3] proposed several recommendations for teaching engineering to young students based on observations she made while introducing materials engineering to kindergarteners and first graders. Among Price's recommendations were:

- Use simple language and simple explanations
- Find analogies to everyday things that they can understand
- Be prepared to explain concepts in two or three different ways

Price discussed issues such as materials selection and magnetism with the children by bringing different materials into the classroom and discussing their properties.

Torres and Casey[4] took Price's suggestions into consideration when they collaborated on a project to teach electrical engineering technology to kindergartners in Pennsylvania. Torres and Casey introduced the children to electricity "by providing the students with first a concept, then asking them to make predictions." The students performed various experiments and tasks to test their predictions, such as connecting a circuit and testing different materials to categorize conductors and insulators.

Several attempts to teach engineering to kindergarteners and first graders also include using the computer as a tool. Engineering Alphabet[5] uses an online course management system, WebCT, to teach engineering to preschool, kindergarten, and first grade students. This tool, developed at Tennessee Tech University, introduces young students to simple engineering terms while teaching the letters of the alphabet. For instance, when students click on the letter J they are presented with words such as jet, jig and jaw. Engineering Alphabet also offers links to Engineering Glossary, Famous Engineers, and What is Engineering, which presents a brief description of different areas of engineering. Engineering Alphabet was beta tested with Northeast Elementary teachers and students in Putnam County, Tennessee, and when this work was presented it was under revision based on feedback received.

The Center for Engineering Education Outreach also used the computer as a tool for teaching engineering. Erwin et al. reported favorable results while introducing mechanical engineering to kindergarteners using LEGO Engineer and RoboLab which allow one to program LEGO motors, lights and sensors through a computer interface. Kindergartners were able to design and program simple robotic cars while learning about friction.[6]

Teaching Engineering through Literary Works

Creative strategies for teaching difficult concepts are not new in the field of education. There is evidence that storytelling and storybooks are effective ways to teach science, social studies, and math to students with a wide range of abilities.[7-11] Many middle schools have adopted the practice of using science-oriented trade books as a component of their science classes.[7] More recently, information has been published on using stories to teach math to first graders. This strategy builds confidence in students who enjoy either reading or math while practicing the skill in which they are less proficient.[12]

We believe that using stories incorporating fictional characters facing situations revolving around the use of tools and materials, as well as the necessity to use the engineering design process to find solutions is an effective strategy to teach Technology/Engineering to kindergarten and first grade students. This strategy allows students to interactively discuss concepts, make predictions, and learn new vocabulary in a teacher-friendly, easily reproducible format. In addition to the literary works, we believe that hands-on activities help reinforce taught concepts. These activities focus on characters in the literature pieces and require the students to solve engineering problems that the characters encounter.

Implementation

At the kindergarten level, the graduate fellows first wrote and illustrated "Sparky's Engineer", an introduction to engineering disciplines. In "Sparky's Engineer," a Dalmatian puppy, Sparky, searches for his owner, who happens to be an engineer. Along the way, Sparky meets many different individuals who each describe an engineer that they know. The fellows also designed "Sparky's Engineer Activity Book", which incorporates drawing, matching, searching, and maze activities based on concepts developed within the story. Before introducing this literature piece in the classroom, the fellows presented the story and activity booklet to WPS teachers at a PIEE summer workshop. The teachers, who were first skeptical of the idea of teaching engineering to kindergarten students, welcomed the story and were excited to bring this literature piece and activity book into their classrooms. Figure 1 shows page 19 in "Sparky's Engineer" where Sparky is perplexed because he has not yet found his owner. Sparky needs to continue on his quest of talking with neighborhood children to learn about engineering and to find his own engineer!

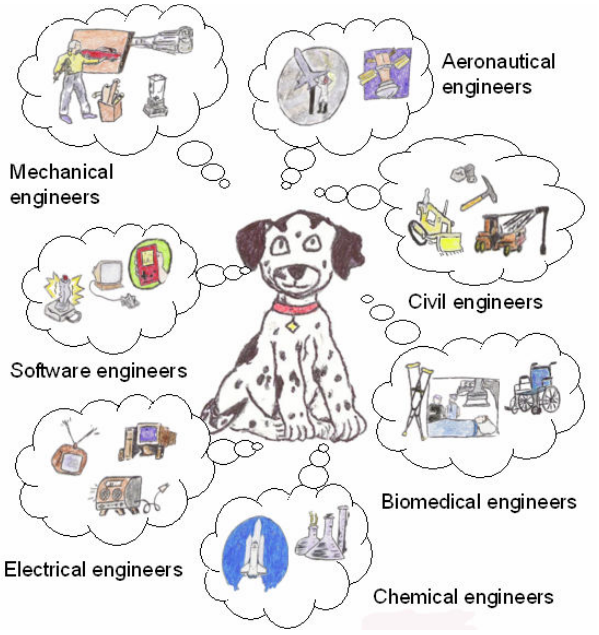

Figure 1. "Sparky's Engineer" page 19. Sparky is reviewing in his mind various types of engineering and what each engineer makes. There is only one problem: his owner is not one of these types of engineers! Sparky must keep on looking to find his engineer!

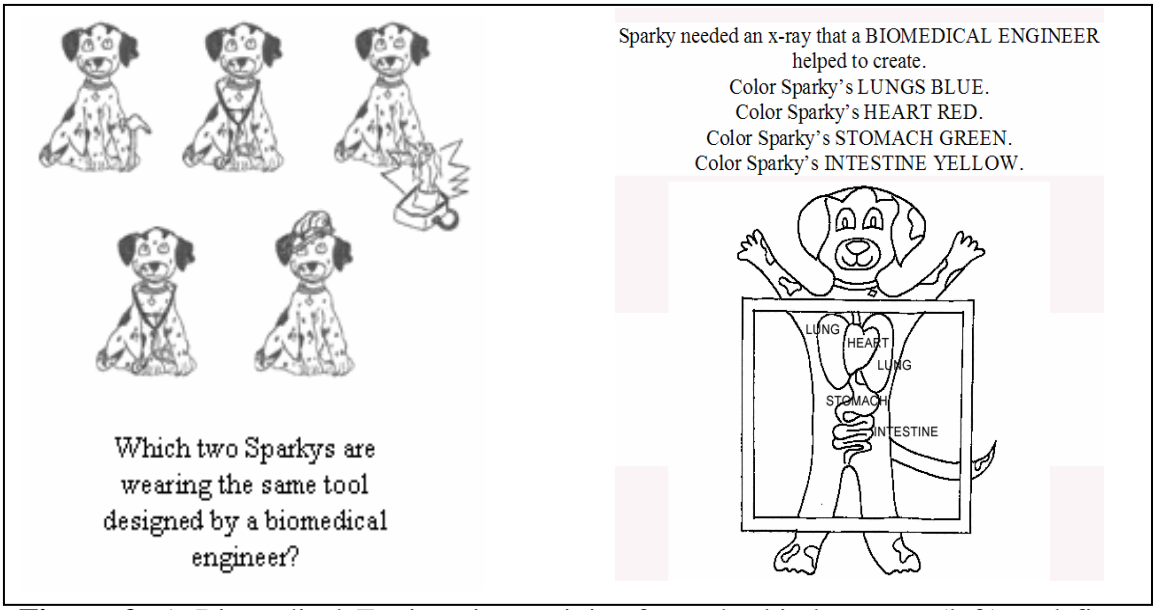

Figure 2. A Biomedical Engineering activity from the kindergarten (left) and first grade activity books.

Following the summer workshop, and the discussions with K-6 teachers, the fellows revised the activity books to the appropriate grade level (Figure 2).

After initial use in the classroom in fall 2005, discussions with teachers, input from undergraduate students, and research helped establish that "Sparky's Engineer" and activities work best in kindergarten and first grade classrooms when taught as a series of four, half-hour lessons. During each lesson, fellows and undergraduate students read five to six pages of the story while explaining new vocabulary words and illustrations, as well as asking questions to encourage discussion. WPS teachers also initiated discussions about new concepts and made certain that potentially confusing ideas were explained in detail before the story continued. After reading, the appropriate engineering work-book activities were completed.

Following this introductory lesson, graduate fellows and undergraduate students created a number of additional stories to teach new concepts in the kindergarten and first grade classrooms. Figure 3 shows the covers of four books of six that were created. "Mr. Fox's Box" will be read in the first grade classrooms to demonstrate Mr. Fox's use of the Engineering Design Process to design a new mailbox. "The Saturday Morning Superhero" was used in the kindergarten classrooms to introduce the Engineering Design Process; a six year old designs his very own superhero costume. "The Five Pilgrims" was read to introduce first graders to manmade/natural materials and appropriate materials selection. "The Greatest Snowball Fight Ever!" was read to first grade students to introduce simple machines, levers, pulleys, and incline planes. "Carl the Construction Worker" provided an interactive story in which kindergarten students selected the appropriate tools to place in Carl's hands while he constructs a new house. All of these stories were accompanied by hands-on activities and delivered in the classroom in a similar manner to "Sparky's Engineer".

Figure 3. Stories Developed for Kindergarten and First Grade. Fellows created stories and created illustrations for the books by hand or means of the web.

Results

After introducing "Sparky's Engineer" in both the kindergarten and first grade classrooms, the children in both grade levels were able to give the definition of an engineer, as "one who uses math and science to help solve problems," and to describe the engineering design process, as found in Figure 4, as "think, design, create, and test." This was the first time that many of the students learned about engineering; without this initial introduction, many of the students would not relate math and science activities to engineering until much later in their education. Shortly after reading "Sparky's Engineer" in one of the first grade classrooms, a student responded on a free writing activity that he "liked to think about engineering."

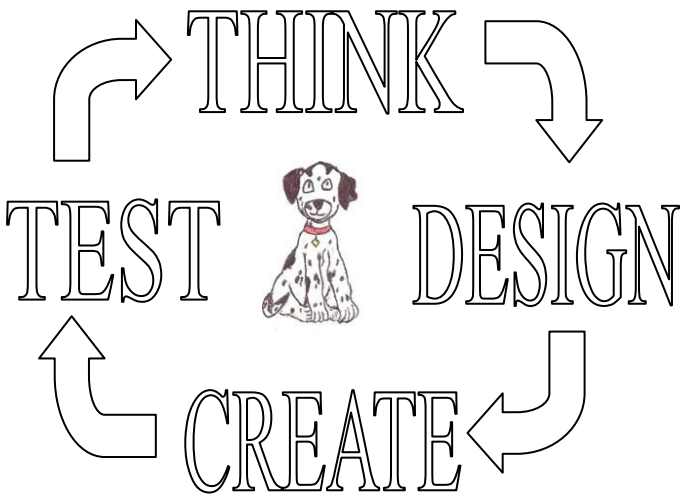

Figure 4. The Engineering Design Process for Kindergarten and First Grade Students.

By separating "Sparky's Engineer" into four sessions, the definition of an engineer, as well as each type of engineer, was able to be reinforced over a period of time. By the end of the sessions, students took pride in being able to answer questions such as: "What does an electrical engineer make?" and "What type of engineer may work in a hospital?" This strategy of sectioning the reading of each book and activities into sessions was used for the other stories in the classroom.

The additional hands-on activities to complement the literary pieces were quite popular in both the kindergarten and first grade classrooms. To complement "The Five Pilgrims," students used the Engineering Design Process to think about what a house requires, to design their house on paper first, to create their house, and to think about what tests they would use such as putting the houses outside to face the elements. This same concept will be applied to "Mr. Fox's Box", when students will design and create mailboxes for Valentine's Day. Students enjoyed the hands-on thinking, designing, and creating of their own houses. Each student wanted to share why their house would be good for the pilgrims and to discuss materials they used, and whether these were natural or manmade, both main objectives of the lessons. Similar results were obtained for "The Greatest Snowball Fight Ever!" with the students understanding how simple machines can be used to perform tasks more easily; students completed an activity involving a lever system to make catapults in the classroom. Marshmallows were substituted as snowballs and a competition was held as to who could catapult the "snowball" the furthest. This required the knowledge of levers and where to position the fulcrum. Through the book and the activity book leading up to this hands-on activity, many students knew where to position the fulcrum without any instruction.

Discussion

Storybooks introduced engineering and the engineering professions in a format familiar to WPS teachers and accessible to students. At a 2005 summer Teachers Workshop, both kindergarten and first grade teachers were delighted with "Sparky's Engineer". They felt the story showed that graduate engineering students were indeed able to "get down to their level." In the classroom, these teachers found storybooks to be an excellent teaching tool.

Young students related well to the stories, which are similar to books they have previously seen. They quickly learned new vocabulary, including terms such as "Engineer", "Chemical", and "Tool". Students remembered characters from the story and associated them with corresponding concepts. The children saw the wide variety of jobs undertaken by engineers and learned about the types of problems that they solve. Perhaps most importantly, the idea of becoming an engineer became more attainable to these students.

Each lesson provided additional insight into the effectiveness of teaching tools at the kindergarten and first grade levels. Repetition and reiteration of concepts were important in ensuring that students understood and retained the material taught. Storybooks were highly effective because teachers could easily refer back to the story in the classroom and because they are all-encompassing lessons for which no additional materials or lengthy instructions are required.

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