

AC 2007-2464: CURRICULUM DEVELOPMENT AND INTEGRATION FOR K-6 ENGINEERING EDUCATION

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Curriculum Development and Integration for K-6 Engineering Education

Abstract

The state of Massachusetts has recognized the importance of introducing students to topics in engineering and technology at a young age in order to better develop the students' understanding of these areas and to teach them how to utilize this knowledge throughout life. In 2001 Massachusetts instituted "Science and Technology/Engineering Curriculum Frameworks" for K-6 classrooms. Massachusetts elementary teachers found themselves unprepared and uncertain of how to teach these subjects to their students. A three year grant from the National Science Foundation provided Worcester Polytechnic Institute (WPI) with the resources necessary to assist Worcester Public Schools (WPS) in bringing technology and engineering into their elementary classrooms. Through the Partnerships Implementing Engineering Education (PIEE) program WPI faculty, graduate fellows, and undergraduate students worked closely with WPS teachers to develop a curriculum in grades K-6 that would address the Science and Technology/Engineering Frameworks and ensure that each year built upon concepts taught in the previous year. Graduate fellows and undergraduate students then helped the teachers bring that curriculum into the classrooms where they both assisted with teaching and also evaluated their lesson plans and activities. WPS teachers provided continuous feedback on which aspects of the new curriculum were and were not effective. The curriculum for each grade was created, tested with WPS students, evaluated, redesigned, and continuously reevaluated until finalized in the spring of 2006. Each curriculum is a compilation of many hands-on activities, thought provoking lessons, and interactive projects meant to highlight the importance of the engineering design process and to incorporate aspects of math, science, writing, and engineering. In the younger grades, primarily K-3, graduate fellows created storybooks to teach engineering concepts such as the engineering design process and simple machines. Individual activity books were created to accompany the stories and reinforce lessons discussed. At the end of the project an internet website (www.wpi.edu/Academics/PIEE/Resources/Lessons/) was created, containing all of the hundreds of lesson plans developed for grades K-6, in an attempt to aid in efficient distribution of the curriculum to any interested teacher. The interactive, grade specific, curricula were met with enthusiasm by the WPS teachers and will provide a powerful resource to aid teachers looking to bring technology and engineering into the elementary classroom.

Introduction

In the workplace, at home, and in the classroom technological advancements are being incorporated in order to increase efficiency, enhance productivity, and develop new and improved methods of reaching our goals. As engineering and technology continue to wind their way into every day life the ability for individuals to understand and utilize these topics is becoming increasingly important to one's success in the professional world. A strong education in these fields is critical in not only instilling basic principles and concepts, but also in allowing students to appreciate their own potential for growth and success. While many high school programs exist to expose students to science, engineering, and technology, studies have shown

that by the fourth grade most students have either decided they enjoy these subjects or have been turned off entirely [1,2]. Therefore it is critical to begin to incorporate these subjects into the elementary curriculum.

In 2001 Massachusetts instituted Science and Technology/Engineering Curriculum Frameworks for K-6 classrooms [7]. These frameworks required that elementary school teachers incorporate specific technology and engineering principles into their classroom instruction. However, K-6 educators have never been required to take engineering courses, and with not curriculum to follow or formal education, teachers found themselves unprepared to teach these subjects to their students.

To aid in the task of bringing technology and engineering into the elementary classroom the National Science Foundation funded a three year grant, entitled K-6 gets a piece of the PIEE (Partnerships Implementing Engineering Education). The PIEE project involves collaboration between Worcester Polytechnic Institute (WPI) and the Worcester Public School (WPS) system. WPI faculty, graduate fellows, and undergraduate students, worked together with the WPS teachers to create individual engineering curricula for grades K-6 from 2003-2006. This paper is a summary and conclusion of the three year project, incorporating aspects of three previously published articles [3, 4, 5]. A primary goal of the PIEE project were to create a sustainable engineering curriculum for each grade level ensuring that lessons build upon one another from year to year, enhancing and reiterating key engineering concepts throughout a student's education. In addition to teaching engineering concepts, the grant was established with the hope of making engineering more enjoyable and accessible to students at a younger age. The project was also meant to create a lasting partnership between the WPI college community and the surrounding public school system.

PIEE Structure and Organization

Each subsequent year of the project saw an increase in the number of teachers, classrooms, and students involved. In the first year, 2003-2004, three WPI faculty members, six graduate fellows, and twelve undergraduate students worked with six WPS teachers in two elementary schools in grades 4, 5, and 6. Teaching engineering to elementary students is a new and difficult task that increases in difficulty as the student's age and knowledge base decrease. Therefore, it was decided to begin curriculum development in the more advanced age groups and move on to younger classrooms as the project progressed and experience with elementary students increased.

In the second year, 2004-2005, 5 WPI faculty members, 6 graduate fellows, 3 undergraduate fellows, and 18 undergraduates worked with 17 WPS teachers in three elementary schools in grades 2-6. The 4-6 grade teams worked to evaluate and refine the first year curriculum while 2-3 grade teams began their first year of development.

In the third and final year of the project, 2005-2006, PIEE teams added grades K and 1 and continued in grades 2-6. Three WPI faculty members, six graduate fellows, and fourteen undergraduate students worked with twenty-seven WPS teachers in three elementary schools. The 4-6 grade teams continued to refine and redesign the curriculum, supporting WPS teachers as they presented the lessons to their students. The 2-3 grade teams refined, evaluated, and finalized their curricula while the K-1 grade teams initiated curriculum development, evaluated, refined, and finalized their curricula.

Working with students in each grade level provided unique challenges for PIEE fellows and undergraduate students. In the initiation year for each grade, fellows and undergraduate students conducted significant research into the personality traits, strengths and weaknesses of the elementary students prior to developing lesson plans. While Kindergarten students are adjusting to their first year in school and are often not yet able to read, sixth grade students prefer new, less repetitive tasks, are able to incorporate deductive reasoning, and have become more socially sensitive [8]. While it was important for each PIEE team to consider the unique situation of students in each grade, it was also critical to ensure that the final curricula built upon one another. Each curriculum was designed to address grade specific frameworks, but it was critical for each team to understand the frameworks and lesson plan topics for the surrounding grade levels to support and build upon previously learned engineering concepts.

While Massachusetts required elementary teachers to incorporate engineering and technology into their curriculum, it is difficult for teachers to fit more lessons into their already jam packed daily classroom schedule. Therefore graduate fellows made it a priority to incorporate additional subjects into the engineering lessons whenever possible. This allowed teachers to address multiple subjects within the timeframe of one lesson and made it more appealing to incorporate the engineering curriculum into their teaching schedule.

Creation of lesson plans

Prior to the start of each school year WPI faculty and graduate fellows met with WPS teachers for a summer workshop. This gathering allowed teachers and fellows to discuss fears and questions regarding the project, initiate relationships, and fellows to better understand the classroom environment and discuss appropriate age activities. This interaction, along with additional research, brainstorming, and testing led to the development of five main teaching tools: though provoking lesson plans; hands on activities/projects; boards; storybooks; and activity books.

The primary component of each grade specific curriculum is a compilation of lesson plans designed to address each framework. Teaching students the terminology associated with engineering and technology concepts was a critical component of these lessons. Each lesson plan provides WPS teachers with a detailed explanation of the procedure, lesson length, seasonality of the lesson, WPS benchmarks and Massachusetts frameworks addressed, key terminology and definitions, required background information, and essential questions addressed. The remaining four teaching tools provided interactive and visual aids for each lesson.

While college schedules are filled with hour-long lectures, elementary school students have a much shorter attention span and will lose interest quickly if asked to sit still and listen to a lesson. Hands on activities not only help to maintain student's attention but also encourage creativity and provide memorable examples of terminology and concepts discussed in the lesson plan. Hands on activities and projects can easily be tailored to students of all ages.

Visual and interactive boards were created to provide clear and constant reminders of important concepts. One of the basic principles of engineering is the engineering design process. Teaching elementary students the engineering design process allows them to better understand the principles of engineering and problem solving in general. Large visual boards displaying the engineering design process and other science and engineering concepts. These boards were hung

up in the classroom all year to reiterate and constantly reinforce the year’s lessons. These boards also reminded teachers of these concepts and provided a visual reminder to reference and reiterate them throughout other lessons. Interactive boards were also created to encourage class participation in the lessons. For example, in the kindergarten a weather board allowed students to change the weather each day and attach weather appropriate clothing to a boys figure. Figure 1 below shows three boards, a simplified engineering design process for younger students, the weather board described, and a more complex engineering design process.

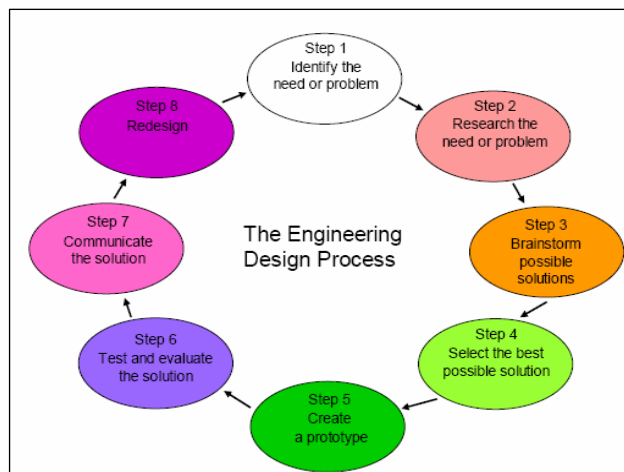
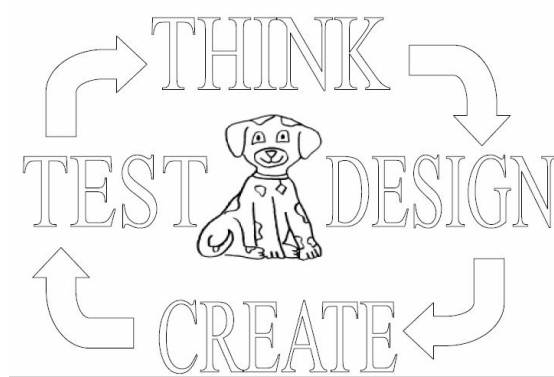


Figure 1: Examples of visual and interactive boards

While lessons in grades 4-6 often incorporate written responses and worksheets, kindergarten students are often not yet able to read and write, while first, second, and third grade students utilize simple reading and writing in the classroom. Storybooks have been used for years to teach various topics in elementary education and fellows felt that books could provide a valuable teaching tool for science and engineering. Graduate fellows wrote and illustrated “Sparky’s Engineer” a storybook introduction to engineering. Sparky was used as a mascot for engineering in grades K-3 and as a way to introduce teachers to the possibility of teaching a seemingly complex topic to young students using a conventional teaching tool. Sparky’s Engineer was an enormous success with teachers and students alike and encouraged fellows to create additional storybooks to teach concepts such as simple machines and materials.

To reinforce the concepts of these storybooks grade specific activity books were created with individual activities for each key component of the lesson. The activity books allowed teachers to revisit and review the story/lesson throughout the year by having the students color in scenes, create their own drawings, and complete mazes and word searches among other activities. An example of an activity from a first grade activity book is shown in Figure 2.

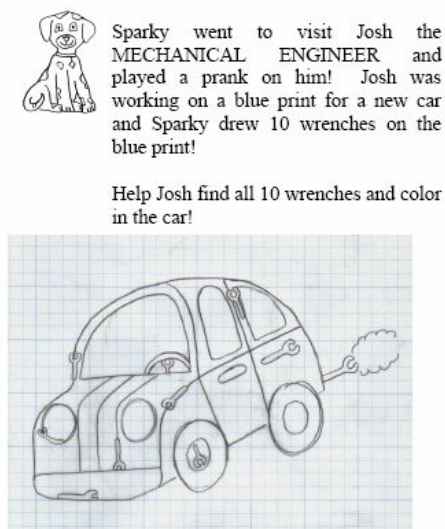


Figure 2: Activity sheet for first grade students

Implementation & Evaluation

While developing lessons and other teaching tools PIEE project teams (specifically graduate fellows and undergraduate students) observed students in the classroom and learned which lessons and tools were most effective. In the initial year of curriculum development PIEE teams taught lessons in the classroom with the support and assistance of the WPS teachers. From a teaching standpoint fellows and undergraduates were able to clearly understand the need for lessons to address student’s unique attention spans, level of understanding, degree of interaction, as well as topics and activities that best maintained the interest of the class. It was challenging to transition from the college environment to the elementary level and full immersion proved to be

a very effective means of understanding the daily challenges faced by WPS teachers. Ineffective and overly complex lessons were clearly evident and adjusted to better suit the grade levels they were created for.

Throughout the first year of development fellows and undergrads observed student response and focused on designing lessons that students enjoyed and retained. By reviewing key concepts throughout the year and evaluating student retention and development, it was possible to identify lessons and tools that aided student learning the most. Following the initial development and delivery, the lessons were gradually shifted into the hands of the WPS teachers. By working with the PIEE project group to design age appropriate lessons the teachers gained confidence in their own ability to teach engineering, at first a foreign topic to many, to their students. The teachers taught lessons developed by the project group while fellows and undergrads observed and evaluated the curriculum to determine the clarity of lesson descriptions, effectiveness in teaching students key concepts, and sustainability. Lessons were considered sustainable if they did not require expensive and cumbersome materials or preparation that was beyond the scope of a school teacher's schedule.

Lessons for grades 4, 5, and 6 enjoyed three years of lesson creation, implementation, evaluation, and assessment. Grades 2 and 3 shortened the process to two years, while grades K and 1 incorporated all development, delivery, and evaluation into one year. The idea of using storybooks to teach engineering began when grades K and 1 entered into the project and all storybooks were written and delivered in the final year of the project. A paper and poster presentation, designed by graduate fellows and principle investigators, described the use and effectiveness of storybooks in teaching engineering to young students [4].

Throughout the three years of the PIEE project lessons were designed, delivered, evaluated, redesigned, redelivered, reevaluated, and so on and so forth until each lesson was considered complete and age appropriate. In the third year of the project one additional undergraduate project team was assigned to review all lessons created in order to ensure that all frameworks for each grade level were addressed in the new curriculum. This team also assessed the flow of material from one grade to another. After the curricula were finalized this project team compiled all lesson plans and materials and created a website to distribute the K-6 engineering curriculum easily and inexpensively to all interested educators [9].

Results & Discussion

Many of the results utilized by PIEE project teams came from evaluating in class student response and daily interactions with WPS teachers. It was clear to fellows working in all grade levels that the introduction of engineering and technology topics at the elementary level sparked great interest among the students. Kindergarten students began using the term engineering on a daily basis and developed the ability to distinguish between various engineering professions that they looked forward to entering into in the future. All students were shown many interesting and appealing ways to use math and science and gained both knowledge and interest in the subjects. A paper detailing the assessment of the PIEE project [6] provides results and various quotes from WPS teachers involved in the project. One teacher proclaimed that "now I stop and think of how I can incorporate engineering concepts into ALL of my science lessons." Another teacher stated that the "units & lesson plans were effective in classroom instruction [and] most importantly, the second graders were "turned on" by engineering." A third teacher said "the PIEE Program has made me a successful and motivated teacher of engineering. I am very comfortable teaching

engineering whereas in the beginning of the program the word ‘engineering’ alone made me uneasy.”

After three years of intensive research, development, and application a full curriculum was created for each elementary grade, incorporating all technology and engineering frameworks set forth by the state of Massachusetts. A positive partnership between WPI and the Worcester Public School system was created and nurtured throughout the project, and will hopefully continue to grow in the future. Engineering was introduced in a hands-on environment in the classroom using familiar teaching tools to make the subject more accessible and less intimidating to students and teachers alike. The primary goals of the Partnership for Implementing Engineering Education were achieved and will hopefully be used to assist many educators in the future as technology and engineering become increasingly important throughout the world.

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