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The TEAK Project: Students as Teachers*

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The TEAK (Traveling Engineering Activity Kit) Project is a program that involves RIT engineering students in the design, construction, and presentation of creative tools for teaching engineering concepts to middle school students in the Rochester, New York community. The TEAK Project is unique in that the college students involved do not only teach engineering, but they create their own instructional materials, lesson plans, assessment tools, and experimental hardware. The result is that, not only do the middle school students see college engineering students as role models and benefit from the early exposure to engineering, but the RIT students involved in the project gain valuable experience as teachers of engineering.

Keywords: Creative tools, experimental hardware, energy and environment.

INTRODUCTION

THE TEAK PROJECT EVOLVED as a way to make engineering outreach work for both pre-college and college students. The need for more workers with an engineering background in the coming years is clear [1] and it is often necessary for students to track into appropriate math and science classes as early as middle school if they are to be ready for a college engineering curriculum. RIT already has very active women in an engineering (WE@RIT) outreach program [2] with a successful infrastructure in place, so it is a natural extension of work already being done within the college to start a program to recruit both young women and men into the engineering disciplines.

Based on feedback from participants in women-in-engineering outreach events at RIT, interaction with college students was always near the top of the list of program features the participants enjoyed [2]. At the same time, RIT students working as lab instructors on-campus or participating in teaching activities off-campus report that they viewed teaching experience as a valuable part of their college careers. Students working as teaching assistants comment that:

- "I really think everyone should do this, it builds a ton of confidence in students which is useful later in their career." (survey response)
- "The TA position that I had was one of my best experiences here at RIT. Throughout my time as a TA I gained greater confidence in myself and my studies, I learned to work with diverse individuals, and I became more interested and excited about the engineering field as a whole . . . The knowledge and confidence I gained will be used greatly during my continuation of my career." (survey response)
- "Nothing cements an idea more than having to teach it." [3]
- "When it came time to teach my very first lab section, all of the preparation seemed to do nothing for my confidence and the realization that someone else's education depended upon me was significant . . .As time went on, my confidence grew and I developed a teaching style all my own . . .[I] had never experienced the level of responsibility accompanying lab instruction and it reaffirmed my passion for teaching so much so that I plan on part-time teaching at community colleges after graduation." [3]

Students participating in teaching in middle and high school classrooms as part of their regular class project activities report that [4]:

- "I used to be confident in my communication effectiveness—this project showed me my flaws and need to tailor presentation based on audience"
- "Really need to know it to teach it"
- "Peaked my interest in this area"
- "I improved my presentation skills a lot"
- "Learned a lot and had fun"
- "Sharing knowledge with future engineers makes me feel good inside. The feeling that you get for helping someone out is priceless. Also, I gained a wealth of knowledge myself in researching this topic. It reinforced what I previously learned in my engineering classes and taught me other uses of gas turbine engines that I can relate to."
- "It is vital for an engineer to learn how to bridge this gap" (between technical and non-technical audiences when discussing engineering related issues).

These data showing students' personal views on how they benefit by working as teachers of engineering is supported by other similar programs,

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such as STOMP at Tufts University [5, 6]. The literature consistently reports that learning by teaching is highly effective, and that brainstorming, troubleshooting, and the act of formulating problems enhance student learning [7–10].

A program, such as the TEAK Project, that involves college students in instructional development and teaching at the pre-college level will benefit all parties involved. For these reasons, the apparent benefits to both pre-college students and college students, the TEAK Project moved forward with college students working as teachers of engineering.

To date, a set of five kits has been developed, centered on a theme of Energy and the Environment. Each TEAK Energy and the Environment kit addresses a different energy-related theme and exposes the target audience to educational activities ranging from basic comprehension to design and evaluation to reflecting on what has been learned. The activities in each TEAK are designed so that they can be completed in two one-hour classroom visits. The students creating TEAK Energy and the Environment used Bloom's Taxonomy as a guideline during program development. TEAK Project learning objectives are focused on middle school or college students and have been categorized accordingly.

Develop a self-sustaining outreach program to provide engineering education resources:

1) Encourage middle school students to consider engineering as a career choice.
2) Teach K-12 students basic engineering concepts related to specific fields of engineering.
3) Introduce middle school students to the scientific method as well as the engineering design process.
4) Create a mechanism to bring engineering activities into local K-12 classrooms.

Create new learning opportunities for RIT engineering students:

1) Help engineering students become more confident in their knowledge of engineering.
2) Increase engineering students' knowledge of the impact of engineering outside the technical realm.
3) Increase engineering students' knowledge of engineering fundamentals.
4) Improve engineering students' communication abilities in addressing non-technical audiences.

The initial focus of the program has been the first set of objectives, involving the development of TEAK hardware and documentation for middle school classroom use.

TEAK DEVELOPMENT

Development of TEAK is highly multidisciplinary, allowing the ability to feature the different ways in which engineers (and non-engineers) from different disciplines can work together on a project. For example, the TEAK Energy and the Environment series has been developed, along with a supplemental interactive website (http://teak.rit.edu), by a multi-disciplinary group of students. The students involved in the TEAK Project include:

- A group of Computer, Electrical, Industrial and Systems, and Mechanical Engineering students designing the original kit hardware and lesson plans with the assistance of an Industrial Design student.
- Students from various engineering departments traveling to local schools to teach students about engineering related to energy and the environment as well as working to refine current hardware based on assessment.
- A group of Software Engineering students designing an administrative framework for an interactive website, along with several games (with input from Mechanical Engineering students on the data required to create a housing simulation game).
- A team of a graphic artist and an information technology/new media student developing a set of characters (The TEAK Squad) embedded in the website and developing games to support the TEAK Energy and the Environment hardware.

All TEAK hardware was originally developed as a Multidisciplinary Senior Design (MSD) project within the RIT Kate Gleason College of Engineering [11, 12], although frequent use has necessitated some repairs and modifications by other students working for the TEAK Project. The design team followed a rigorous design process, including identifying customer needs and engineering metrics to measure success; benchmarking competitors' products; generating concepts and objectively identifying the best concept for development; and the analysis, design, and testing required to deliver a functional working prototype to their customers. The design team created all of the original kit hardware along with the complete lesson plans, meaning that they were involved in the instructional design process before visiting any classrooms to teach the material. Several members of the design team continued to remain in contact with the faculty advisors after graduating and published a paper detailing their involvement with TEAK at an American Society for Engineering Education conference during 2007 [11].

The customer needs determined by the MSD team fell into several broad categories: educate regarding energy and the environment while creating safe, portable, and interactive educational materials. A detailed list of needs is shown in Table 1. To ensure that customer needs were met, the team also developed a set of engineering metrics against which to test the final product. The engineering metrics and specifications for satisfactory design are shown in Table 2.

Over the course of two academic quarters, the

Table 1. Customer needs [11]

Educates About Energy And The Environment • Should support NYS curriculum • Completed in a reasonable time period • Concepts relate to a larger system • Things students can see or do at home • Not intimidating to presenters • Discusses the role of engineering In society	**Interactive** • Involves all levels of Bloom's Taxonomy • Is enjoyable for middle school students • Allows experimentation
Safe • No hazardous materials • Does not require hazardous waste clean-up • Operable by middle-school students • Clear step-by-step directions • No sharp corners • Low voltage • Ability to stop mid operation • Wires insulated properly • Operation and safety sticker	**Portable** • Lightweight • Easy to move • Fits Into average car trunk • Durable • Easily assembled/disassembled • Waterproof container • Prevents spills • Ergonomic design

Table 2. Engineering metrics/specifications [11]

Engineering Metrics	Specifications	√ if met
Weight	< 50 lbs	√
Dimensions	15.8 ft^3	√
Parts (#)	< 100 per kit	√
Assessment tests	Demonstrate improvement	√
Hand-on time	> 30 minutes	√
Average length per kit	2 hour	√
Blooms Taxonomy test	≥ 1 Meets evaluation level	
Steps to assemble (#)	< 30	√
Steps to disassemble (#)	< 30	√
Time to assemble	15 minutes	√
Time to disassemble	5 minutes	√
Tools required (#)	0	√
Flammability rating	0	√
Toxicity rating	0	√
Explosive material rating	0	√
Fragile parts (#)	0	
Voltage	< 9 volts or standard outlet	√
Emergency shut down (y/n)	Y	√
Temperature limit	150 degrees	√
Force able to withstand	200 lbs	
Handles (#)	≥ 2	√
# of times it can be dropped	50	
Take home activities (#)	≥ 1 per kit	√
Time to prepare	1 hour	√
Life expectancy	10 years	?

MSD team developed a prototype kit, tested it with small groups of middle school students, and then proceeded to construct the remaining kits. Within the two course sequence, the Mechanical, Electrical and Computer engineers contributed primarily to the design and analysis required to develop the different activities. The Industrial and Systems Engineering students handled documentation (with support from the Computer Engineering student) and assessment issues, and the Industrial Design student worked with the engineers on construction of the actual devices. Kits developed to date in support of the Energy and Environment TEAK set include Heat Transfer, Chemical Energy, Electrical Energy, Solar Power, and Wind and Water Power. Each kit includes the following documentation and hardware:

- Instruction Manual: this consists of a guide sheet, lesson plans, handouts, and assessment forms. The contents are available online so teachers can browse and decide which kit(s) to use or prepare ahead of time for the kits that they have already reserved.
- Academic Activity: an introductory hands-on activity that helps students start thinking about the energy related topic, certain key concepts, and basic terms.
- Main Activity: an interactive, hands-on and time-intensive activity, requiring students to apply concepts from the Academic Activity to a design and/or analysis problem.
- Take Home Activity: an activity the students perform at home illustrating the ways in which engineering plays a role in their everyday lives.
- Pre and post activity quizzes on specific topics related to each kit.

The Chemical Energy Kit (Figure 1) contains activities for the students to gain a better under-

Fig. 1. An RIT engineering student a group of home-schooled students through the fruit battery experiment in the Chemical Energy Kit.

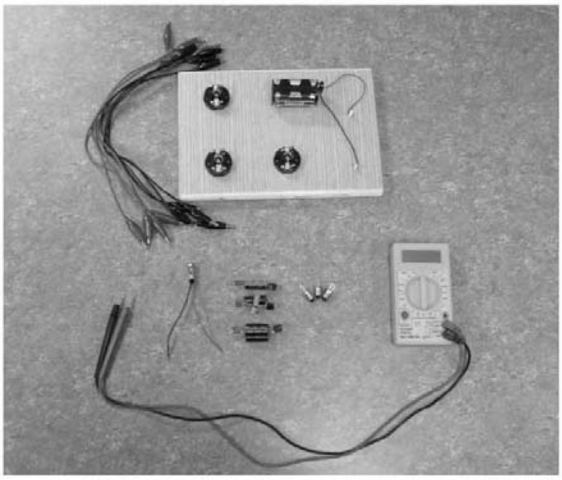

Fig. 2. Key components of the Electrical Energy Kit.

standing about chemical energy, its use in creating mechanical, electrical, thermal, and light energy, how chemical energy is used in a diesel/internal-combustion engine to create mechanical work, and current research into alternative fuel sources. Basic concepts of chemical energy including transfer of electrons between two substances, oxidation, combustion, heat and light are presented.

- In the first Academic Activity, students build H_2, O_2, H_20, NH_3, CO_2, CH_4, and C_8H_{18} molecules to learn about bonding and electron sharing.
- In the second Academic Activity, creation of a fruit battery, students see how chemical energy can be harnessed from surprising sources. The fruit will light a light-emitting diode (LED) that requires ~2.5 volts and a current of ~20 mA. A single piece of fruit with a single zinc nail and a single copper nail will not light the LED, as it provides only an average of 0.54 volts. Students must demonstrate an understanding of power sources linked in series to light their LED successfully.
- In the Main Activity, students use a small fuel cell car to see the physical manifestation of what happens when water molecules are broken apart or formed; this ties into the first Academic Activity. The fuel cell car was chosen because it relates fundamental concepts of molecular bonding to chemical energy and shows how these molecules can create electricity that can then be used to power a car in a more environmentally friendly manner.
- In the Take Home Activity, students evaluate environmental concerns associated with using different types of vehicles in their take home activity.

The Electrical Energy Kit (Figure 2) introduces students to fundamental concepts related to storing and distributing energy. Students construct simple circuits and analyze the electric potential of the designs they create. Concepts that are covered include the concepts of charged particles, the ability of some circuit elements to store charge, and power consumption in a circuit and in physical devices.

- In the Academic Activity, students learn terminology related to electronics and discuss concepts such as closed versus open circuits, resistance, and capacitance. These terms are important for completion of the Main Activities.
- In the Main Activity, students construct two circuits, each with a battery pack powering three light bulbs. One circuit has the bulbs in parallel and the other has bulbs in series. The students use multimeters to measure the current and voltage across each light bulb and discuss how this relates to the way power is distributed to individual homes in the community. If this is completed the students can additionally charge a capacitor, timing how long it takes the capacitor to discharge across an LED. The students use three different sized capacitors and compare discharge times, then discuss how this relates to the way energy is stored before use.
- In the Take Home Activity, students compare the cost to operate different electrical devices with different levels of power consumption.

The Heat Transfer Kit (Figure 3) lets students learn about the transfer of energy in the form of heat. Middle school students learn that heat is based on three things:

1) the temperatures of the material and surroundings,
2) the mass of the material,
3) the material's composition.

They also learn that heat moves naturally from warmer to colder objects and is transferred by conduction, convection, and radiation.

- In the Academic Activity, students explore the difference between heat and temperature, and the different modes of heat transfer. They feel and measure the temperature of different sized balls made from different materials held in a

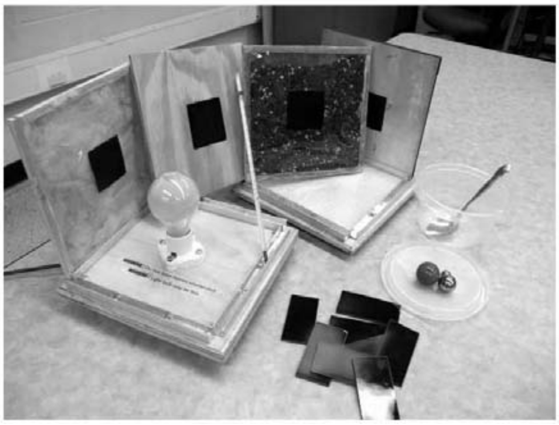

Fig. 3. Key components of the Heat Transfer Kit.

constant temperature warm water bath, then use thermal crystals to visualize the rate of temperature change during conduction (touching with their hands) and convection (exposed to air).

- In the Main Activity, students build a small house using different types of insulation. The house is a cube with a floor, ceiling, and four walls made of four different materials: potting soil, fiberglass insulation, aluminum, and wood. The interior of the house is heated with a light bulb, and students calculate the rate of heat transfer through each of the four materials by taking temperature measurements and using the one dimensional heat transfer equation. The materials were chosen because each represents a common building material and has a different thermal conductivity.
- In the Take Home Activity, students are asked to review their old home heating bills and think about the reasons for differences in the bills over the course of the year. They also look through their home for sources of heat loss and make suggestions about how to improve the insulation.

The Solar Power Kit (Figure 4) teaches students about the ways in which solar power can be harnessed and introduces the concept of the energy cycle. Students learn about renewable, nonpolluting energy sources and some of the challenges that go along with collecting this energy.

- In the Academic Activities, students learn about the solar cycle, the different sources communities use to get their electricity, and how renewable resources like solar power can be used to provide electricity. Students also use a solar oven to cook a frozen pizza, and discuss ways in which solar power can be used for water and home heating and not just generating electricity. Based on tests the team conducted, the oven could reach 285° F at an insolation of 1020 W/m^2, which would be typical of a sunny day in Rochester, New York.
- In the Main Activity, students are provided with a small photovoltaic cell with an attached, regulated LED display and asked to go outdoors and gather solar energy themselves. The LED display segments the varying voltages from the photovoltaic cell, showing variation between brightly sunlit areas, cloudy areas, shady areas, and an indoor setting. As the amount of direct solar energy to the photovoltaic cells increases, more lights on the bar graph will light up; this then shows what conditions are best for using photovoltaic cells to provide electricity.
- In the Take Home Activity, students look for products they use every day that can be powered by solar energy.

The Wind and Water Power Kit (Figure 5) also teaches students about renewable and nonrenewable energy sources, as well as how turbines work.

- In the Academic Activity, students look at different sources of energy and discuss which are renewable and which are nonrenewable, as well as why they place each source into its category. Students also use a small hand-powered generator that lights a bulb to see how rotational energy can be converted to electricity.
- In the Main Activity, students compete to see

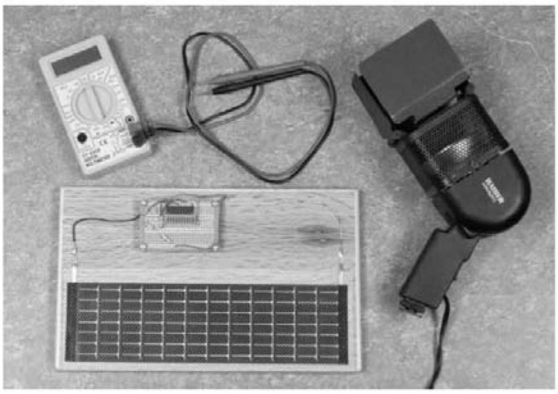

Fig. 4. Key components of the Solar Power Kit, including a light gun for groups that are unable to go outside to collect solar energy.

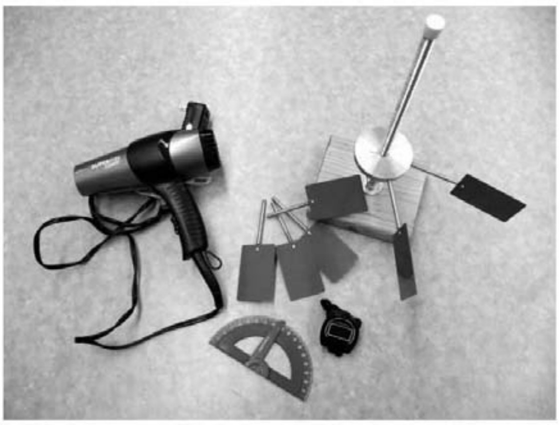

Fig. 5. Hardware for the wind turbine activity in the Wind and Water Power Kit.

who can design the most efficient windmill, tying in with the Academic Activity regarding generators. Each team is given a hub that threads onto a rod. Teams place blades onto their hubs, and decide how many blades to attach to the hub, and at what angle the blades should be placed. Using a hair dryer to simulate a source of wind, teams test to see whose design moves the hub up the threaded rod the fastest.
- In the Take Home Activity, students are asked to look around their homes or places they visit to find sites that might be good candidates for wind- or water-based power plants.

In order for the TEAK Project to be successful in bringing engineering into K-12 classrooms, it is critical for the designers to identify expected learning outcomes and demonstrate how TEAK activities map to NY State Math, Science, and Technology (MST) Education Standards [13]. MST standards are provided in the appendix for reference, and all activities are mapped for elementary students. Tables 3–7 show the learning outcomes for each in-class activity, along with the MST Standard(s) addressed.

After development of the hands-on activities, a second senior design team proceeded with development of a TEAK website called TEAKTown. This team, made up entirely of Software Engineering students from RIT's Golisano College of Computing and Information Science, created an administrative framework that allows future students to easily improve and expand the web content as the TEAK Project evolves. The team also created an initial set of activities:

- a game to design the most energy efficient house while keeping your family happy,
- a Pac-Man-style arcade game based on "munching" up the correct engineering facts,
- a sledding hill that allows players to explore different fields of engineering,

Table 3. Chemical Energy activities, outcomes, and MST Standards addressed

Activity	Outcomes	MST
Build molecules	Explain the Bohr model of the atom.	4
Fruit battery	Explain how energy is generated from fruit and other alternative energy sources. Recognize that energy can be found in unexpected places. Recognize that elements can be placed in series to produce more power.	4,7
Fuel cell car	Explain the electrolysis process. Recognize that energy can be created safely and in an environmentally sound way through alternative chemical sources.	4,7

Table 4. Electrical Energy activities, outcomes, and MST Standards addressed

Activity	Outcomes	MST
Discuss terminology	Explain the difference between insulators and resistors. Provide examples of resistors and capacitors Explain how a capacitor stores charge Explain the difference between current and voltage. Relate concepts of grounding to real-life situations.	4,6
Build series and parallel circuits	Predict whether or not a circuit will conduct electricity (open vs. closed circuit). Explain the difference between parallel and series circuits.	1,3,5,7

Table 5. Heat Transfer activities, outcomes, and MST Standards addressed

Activity	Outcomes	MST
Heat vs. Temperature and thermal crystals	• Describe items as relatively hot or cold and estimate temperature. • Differentiate between heat and temperature. • Investigate volume changes during heating of a liquid. • Identify that heat moves from areas of high to low temperature. • Explain how color affects temperature change.	4
Insulation house	• Investigate heat transfer by conduction, convection, and radiation. • Explain the difference between conductors and insulators. • Recognize that light bulbs emit both light and heat energy. • List ways of producing heat and classify as mechanical, chemical, nuclear, or electrical. • Investigate and explain the use of insulating materials to minimize heat transfer.	1, 3,5,7
Take home: review old home heating bills	• Identify that seasonal changes affect the amount of energy required to heat/cool a house. • Predict the most expensive months based on past energy bills. • Identify ways in which a home could become more energy efficient.	2,6

Table 6. Solar Power activities, outcomes, and MST Standards addressed

Activity	Outcomes	MST
Discuss solar energy applications	• Explain why solar energy could be beneficial. • Explain the use of solar energy in both heating and electricity generation applications.	4,6
Compare solar energy collection sites	• Explain why photovoltaic cells need to be in direct sunlight to generate electricity. • Explain the limitations of solar energy.	5,7
Take home: identify items that can be powered with solar energy	• Identify various everyday products that use or could use solar energy.	1

Table 7. Wind and Water Power activities, outcomes, and MST Standards addressed

Activity	Outcomes	MST
Discuss renewable vs. nonrenewable energy, turn rotational energy into electrical energy	• Differentiate between renewable and nonrenewable energy sources, and give examples of each. • Explain why wind and water are renewable energy sources.	4,6
Windmill design	• Explain how wind turbines produce electricity. • Optimize the design of a wind turbine. • Recognize that the speed and direction of the wind affects the turbine. • List advantages and disadvantages of using wind as a source of electricity.	1,5,7
Take home: find local sites that might suit wind or hydroelectric plants	• Identify ways in which wind and water were used to do work before the discovery of electricity.	4,6

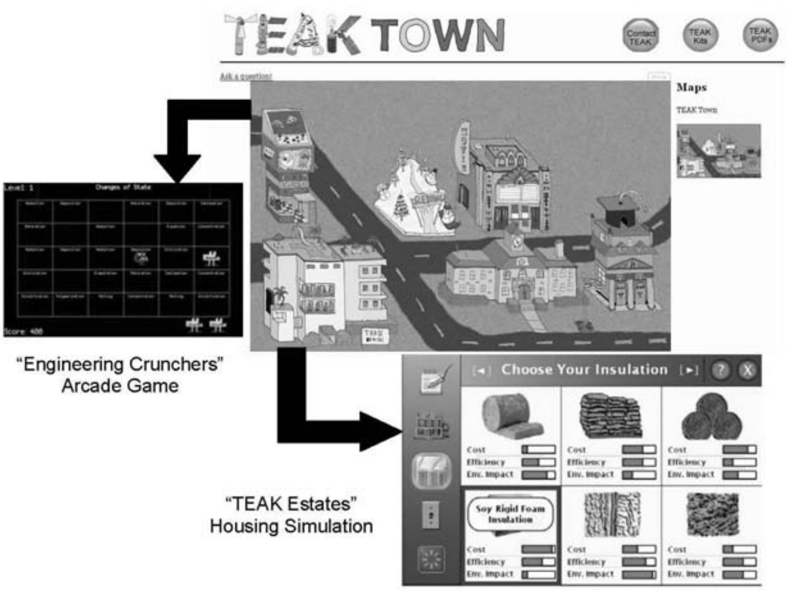

Fig. 6. TEAKTown website screen shots.

- a College Town where visitors can "meet" RIT engineering students to find out about what it's like to be an engineer,
- a library and movie theater where visitors can browse facts and video clips on different areas of engineering.

Figure 6 shows some samples of website content; more information is available at http://teak.rit.edu/teaktown.

Students have been involved in every aspect of TEAK Development since the launch of the program during the 2005–06 academic year. Besides the eight students who designed the original kit hardware and the five Software Engineering students who created the website, many other students have been involved in different aspects of TEAK. Five students worked as instructors in the TEAK program; two of these students had prior experience working with young women in

Fig. 7. An RIT engineering student leading a group of 6th grade students through an experiment to illustrate the difference between heat and temperature. The RIT student worked part-time for several quarters on the TEAK project.

engineering outreach programs, but the other three were members of the American Society of Mechanical Engineers (ASME) who were interested in engineering outreach. Another three worked on improving kit hardware and two of them also continued to become instructors. Two students worked on the website: one was an engineering student populating the site with factual content and the other was a graphic artist creating characters (Figure 8) and an environment for TEAKTown (the map shown in Figure 6). Another two students did technical writing work, revising lesson plans. One of the two had worked as an instructor and made revisions based on her experience in the classroom and the other contributed mainly by improving the overall quality of the writing in the documents. To date, 24 students have worked to make The TEAK Project what it is today, with more students continuing to apply for future work on the project.

TEAK IMPLEMENTATION

With so many different individuals from different departments and colleges involved in the TEAK Project, implementation is not a trivial matter. The project is overseen by two faculty members and one staff member. The faculty members primarily advise senior design teams and student workers on technical matters and instructional materials and the staff member coordinates all kit reservations, kit checkouts/returns, student hiring and payroll, and transportation to off-campus sites.

The TEAK Project is set up to build a pipeline of students who are prepared to teach engineering in area classrooms and extracurricular events. Students typically begin working on the project as part-time workers doing kit development and/or

Fig. 8. The TEAK Squad: characters created to enhance the appearance of TEAKTown.

improvement; this gives them an opportunity to learn about TEAK and become familiar with the kits. After working in this role, some of the students will continue, to become TEAK instructors (Figure 7). Current practice is to send out an experienced instructor with a new instructor: this is one of the benefits of having students work in teams of two. In addition, the engineering student teams consist of a female and male student in order to mirror typical middle school classroom demographics.

The students working on TEAK participate through a variety of mechanisms. Many students are taking a course that involves a significant design project, such as a capstone Senior Design, and thus receive class credit for creating new TEAK materials. Most of the remaining students are paid employees. The largest number of paid employees, both men and women, are identified through the Women in Engineering (WE@RIT) program. Others have been identified by faculty members as students who have a particular interest that aligns with a TEAK Project need. As indicated previously, a final small group of students became involved through an ASME outreach effort.

In an effort to ensure the TEAK Project's sustainability, a cost model has been developed and will be put into effect beginning with the 2008–09 academic year. The goal for the TEAK Project is to come as close to breaking even as possible, to ensure that lack of continued donor support would not mean the end of the program. Based on post-TEAK surveys from teachers who have checked out kits or had students visit in the past, a typical teacher is willing to spend anywhere from $25-$75 for use. The student time required for a visit, including kit preparation, review of lesson plans, and post-visit kit inventory and repair is approximately four to five hours per visit for two students; the time required for a single student to prepare a kit for teacher checkout and inventory it after return is approximately one hour per checkout. The preliminary model involves a charge of $35 for a teacher to check out the kit and use it, or a charge of $75 for two RIT students to come into the middle school classroom and do all of the instruction.

Table 8. Numbers of students whose answers to technical questions showed improvement from pre-TEAK quiz to post-TEAK quiz

Kit/Activity	**Number of students showing improvement**
Chemical Energy Kit	
Fuel Cell Car Activity	15/17
Electrical Energy Kit	
Series Circuit Activity	8/27
Capacitor Activity	9/21
Electricity Cost Activity	6/27
Heat Transfer Kit	
Heat vs. Temperature Activity	15/28
Thermal Crystal Activity	14/28
Insulation House Activity	17/28
Solar Power Kit	
Solar Oven Activity	20/38
Wind and Water Kit	
Renewable vs. Nonrenewable Energy Activity	5/17
Wind Power Activity	10/21

TEAK ASSESSMENT

The TEAK Project has been assessed on several different levels. Using pre- and post-instruction quizzes, student learning can be assessed. Teacher satisfaction with the TEAK experience is currently assessed using a survey to be completed and returned as part of the kit check-in process. Finally, the students working on the TEAK Project are assessed; at the present time, that assessment is only in the form of grading the senior design teams working on the project, and that is an area for improvement.

Each TEAK includes pre- and post-activity quizzes that focus on specific topics related to the kit that was used in a particular class. These quizzes have identical questions, except that the post-activity quiz also asks, "Did you enjoy this activity? What did you like best?" and, "What did you like least? Do you have any other comments?" This allows direct comparisons between the quality (and presence or absence) of each answer for each student before and after completing the activity. Each quiz, regardless of kit topic, also includes the question, "Would you consider becoming a scientist or engineering when you grow up? Why or why not?"

To date, slightly more than 100 students have actually completed the pre- and post-activity assessments, and the results are very favorable. With respect to the first TEAK Project learning objective to encourage students to consider engineering as a career, 91/102 students indicated increased interest in becoming a scientist or engineer after exposure to TEAK. The second TEAK Project objective, to teach students some basic engineering concepts, has been more difficult to evaluate. In some situations, many students in a class were already somewhat familiar with the engineering concepts discussed and therefore showed no improvement after participating in a TEAK activity. However, in groups where students did not generally have prior knowledge, there have always been at least a subset of the group who showed increased knowledge of engineering concepts after exposure to TEAK. Details of student responses are given in Table 8.

With respect to the final two TEAK outreach-related objectives, teaching about the scientific method and design process and creating kits that can be brought into local classrooms, the basic design of the kits ensures that these objectives are inherently met. Each kit includes a worksheet for using the scientific method to answer at least one question as well as a design activity, and the kits are all easily contained in portable plastic storage bins.

Feedback from the four teachers who filled out the post-TEAK survey has also been favorable. Teachers were asked to identify what they and their students liked and disliked about TEAK, the most and least useful documentation provided to them, and whether or not the time estimates for each activity were accurate for their group. In general, teachers and students enjoyed the hands-on nature of the activities, with one teacher noting that he appreciated the fact that there was minimal assembly required so that the students could focus on the engineering-related hands-on work. Negative comments generally referred to malfunctioning equipment (such as LEDs, light bulbs, or batteries) or that some material was at too high a level for their students. Everyone responding felt that the time estimates for each activity were accurate, but that they did not encourage or require students to complete the take-home activities. Each respondent also expressed interest in checking out more TEAK kits in the future. As a whole, for the limited responses received, teachers have been very satisfied with their TEAK experiences.

SUMMARY AND FUTURE WORK

The TEAK Project has been quite successful, with hundreds of pre-college students participating over the past three years. Teacher feedback has been favorable, pre-college students seem to enjoy learning about engineering, and the RIT students involved so far have found the experience to be valuable. While the TEAK Project has been well received in classrooms and extracurricular groups, there are several areas for improvement.

First, many students have expressed frustration with the pre-activity assessments, and do not understand that they are not supposed to know the answers before they complete the activity. This has led to some instructors eliminating the assessment part of TEAK completely, and makes it difficult to demonstrate an ability to help teachers meet their state educational standards. The student assessment will be redesigned in the coming year to include more oral, group-level assessment and written post-activity assessments with clearer expectations. Related to this, adults who check the kits do not always fill out their post-TEAK surveys; this issue also needs to be addressed so that this useful feedback can be obtained and used to help improve the TEAK Project.

Second, as mentioned previously, the RIT students working as instructors and designing activities and lesson plans are not currently being evaluated to determine what they gain from the experience. A formal pre- and post-TEAK assessment for college students will be designed in the coming year as well, in an effort to evaluate RIT students' improvements in understanding of core engineering materials, communication skills, and confidence.

Finally, the current kit activities and website are limited to energy and environment related topics. Future plans include creating new TEAK series for a variety of different engineering topics (e.g., bioengineering, transportation, or materials) and creating lesson plans for the existing kit hardware to be used in other grade level classrooms. In addition, engineering students will begin working more closely with graphic design and information technology/new media students to create additional games for the website related to a wide variety of engineering topics.

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APPENDIX: NY STATE MATHEMATICS, SCIENCE, AND TECHNOLOGY STANDARDS [13]

Standard	Area	Description
1	Analysis, Inquiry, and Design	Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.
2	Information Systems	Students will access, generate, process, and transfer information using appropriate technologies.
3	Mathematics	Students will understand the concepts of and become proficient with the skills of mathematics; communicate and reason mathematically; become problem solvers by using appropriate tools and strategies; through the integrated study of number sense and operations, algebra, geometry, measurement, and statistics and probability.
4	Science	Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.
5	Technology	Students will apply technological knowledge and skills to design, construct, use, and evaluate products and systems to satisfy human and environmental needs.
6	Interconnectedness: Common Themes	Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.
7	Interdisciplinary Problem Solving	Students will apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.

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