AC 2011-167: BEST PRACTICES IN K-12 AND UNIVERSITY PARTNERSHIPS PANEL

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Mercedes McKay is Deputy Director of the Center for Innovation in Engineering and Science Education at Stevens Institute of Technology. She is chair of the 2011 Best Practices in K-12 and University Partnerships panel committee for the K-12 division.

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Stacy S. Klein-Gardner serves as Director of STEM Outreach for the Vanderbilt University School of Engineering and Peabody College.

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Kathy Zook has been teaching for 27 years, both at the elementary and the middle school levels (primarily grades 2 - 6). She has a MA in Special Education with emphasis in gifted and talented education.

Megan Yoder, Colorado School of Mines

Barbara M. Moskal, Colorado School of Mines

Barbara Moskal received her Ed.D. in Mathematics Education from the University of Pittsburgh. She is a Professor of Mathematical and Computer Sciences, the Interim Director of the Trefny Institute for Educational Innovation, and the Director of the Center for Assessment in STEM at the Colorado School of Mines and an Associate Editor for the Journal of Engineering Education. Her research interests are educational project assessment and evaluation, K-12 Outreach and gender equity in STEM.

Michael Hacker, Hofstra University

Michael Hacker is Co-director of the Center for Technological Literacy at Hofstra University and serves as the PI of the NSF DR K-12 Project Simulations and Modeling for Technology Education (SMTE). He has served as PI or Co-PI on nine other large-scale NSF projects focused on improving teaching and learning in K-16 STEM education. His grant writing and project management expertise have resulted in $27M of federal funding for STEM programs with a focus on technology and Engineering education.

He formerly served as a classroom teacher, department supervisor, and university teacher educator. As the New York State Education Department (NYSED) Supervisor for Technology Education, he co-managed the development of the New York State Standards for Mathematics, Science, and Technology. He also served as a member of the team that developed the national Standards for Technological Literacy. For 47 years, Technology Education has been at the core of his professional life.

Hacker is a member of the International Technology and Engineering Educators Association (ITEEA) Academy of Fellows, received the Epsilon Pi Tau Distinguished Service and Laureate Citations; the ITEEA Award of Distinction, and State Supervisor of the Year award; and the Institute of Electronics and Electrical Engineers Mathematics and Science Education Award. He has served in a leadership capacity in his state technology education association (New York) and has received the NYSTEA President’s Award after serving as NYSTE President.

He has authored five secondary school textbooks, numerous journal articles, co-edited several scholarly compendia and international conference proceedings, and has served repeatedly as an NSF expert panel reviewer.

M. David Burghardt, Hofstra University

Professor of Engineering and Co-director and founder of the Center for Technological Literacy at Hofstra University has been involved with K-12 engineering education for over 20 years. He has been the Principal Investigator or co-Principal Investigator on six NSF grants dealing with interconnected learning in STEM with a strong focus on the E. He is the author of twelve texts, numerous articles and many presentations related to STEM learning in K-12.

David Crismond, City College of the City University of New York

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David Crismond is an Associate Professor of Science Education at the City College of New York. Crismond’s main research interests revolve around K-16 science and engineering cognition and pedagogy, and teacher professional development in these areas. Crismond recently completed a collaborative NSF-funded project with Tufts University that developed software called the Design Compass that supports students’ reflective thinking while designing. With Purdue’s Robin Adams, he is developing a representation of design pedagogical content knowledge, and is currently teaching graduate courses for in-service K-8 teachers that emphasize doing literacy- and math-enhanced hands-on science and engineering activities with students.

Mr. Chris Malanga
Timothy James Johnson, S. F. Austin High School - Houston ISD

Timothy Johnson has been employed as a teacher at SF Austin High School in Houston Independent School District in Houston, TX since 1985. His educational background includes a BS and MS in Chemistry from Texas A&M University in 1973 and 1975 respectively. Current teaching responsibilities are AP Physics and a Project Based Learning class entitled Scientific Research and Design focused on aerodynamics. He has been teaching twenty five years at Austin High, teaching Physics, Chemistry, Dual Credit Chemistry and Physical Science and also two additional years in Luling, Texas. His passion and goal is to prepare students on a daily basis for the next level in their education process - college and STEM careers beyond that. In addition to his teaching assignment he serves as the Science Department Chair which involves leading a team of nineteen teachers. This includes assisting in the areas of pedagogy, science content and course development. Recently Austin High achieved the level of a recognized high school in the State of Texas based on scores in all four core content areas. They are pushing on to the exemplary level this year and beyond. He is the co-sponsor of the DREAM program with Rice University and also the co-sponsor the Science Club.

Prof. Brent C Houchens, Rice University
The **K-12 and Pre-College Engineering Division** of ASEE is recognizing exemplary K-12 – university partnerships in engineering education at the 2011 ASEE Annual Conference and Exposition in Vancouver, Canada. To do this, the Division is sponsoring a panel session on Best Practices in K-12 and university partnerships. Submissions chosen for participation in this session demonstrate a true partnership between a K-12 school (or schools) and an engineering school/college at a university.

Selected partnerships have *data to support proven success in the classroom* and demonstrate *engineering engagement and knowledge acquisition* by K-12 students through age appropriate activities and lessons. Best Practices Partnership Panel winners’ papers are authored collaboratively between engineering and technology education faculty and K-12 teachers. Details on *the partnership's structure and goals*, *the strategies employed to overcome challenges and obstacles*, and *successes and lessons learned* are included. Each partnership’s description includes sample student product(s) and conveys how other partnerships may emulate the project.

One proposal winner was chosen by a panel of reviewers at each of the following levels: preschool or elementary school; middle school; high school. The three winning abstracts have been used to create a conference paper for this session.
Partnership Structure

As part of the Bechtel K-5 Educational Excellence Initiative, funded by the Bechtel Foundation, graduate students in mathematics, science and engineering are placed in support of elementary school teachers from Adams County District 50 and their students for up to fifteen hours each week during the academic year. Teachers are recruited to the program in cohorts. Each cohort consists of a kindergarten, first, second, third, fourth and fifth grade teacher, all drawn from the same elementary school. One graduate student from the Colorado School of Mines is assigned to support each cohort, while another graduate student provides half-time support between two cohorts or two schools. Using this structure, each participating school receives approximately 22 hours of support each week throughout the academic year. Sharing a graduate student across grade levels is possible because elementary teachers are generalists who provide instruction on multiple subjects and typically spend as little as 45 minutes each day on mathematics and/or science. In 2010, 24 teachers participated in this program, impacting approximately 750 elementary school students throughout the academic year.

During the summer prior to classroom placement, graduate students receive instruction on elementary education, literacy in mathematics and science classrooms, cultural differences and effective strategies for working with diverse populations. Participating teachers attend a ten day, six hour per day summer workshop, that is offered simultaneous to the graduate student summer session, and this workshop addresses the applications of mathematics and science to engineering. Joint sessions are held during the summer session among graduate students and teachers, allowing for collaboration and brainstorming on lesson plans that will be implemented during the academic year. The bond between the graduate students and the teachers begins to develop during the summer and is strengthened throughout the academic year. These workshops are taught in collaboration with expert district teachers, university faculty, and engineers and scientists from a local national laboratory. Each workshop further offers the option of continuing education credits which are necessary for participating teachers to maintain state teaching certification. Each participating teacher has the option of remaining in this partnership for up to two years.

The schools in Adams 50 are largely Hispanic, presenting both language and cultural challenges. Additionally, the district is in its second year of implementing Standards-based System (SBS), a program where the students are grouped according to ability level rather than chronological grade level. The implementation of the SBE program presents its own unique set of challenges,
such as teaching to multiple levels in each classroom and helping students to monitor and evaluate their own learning targets.

**Partnership Roles**

The graduate students’ role in the classroom is to share their excitement, knowledge and research of mathematics, science and engineering with the students and teachers in the classrooms. A common first report of graduate students is surprise that neither the teachers nor students immediately accept or understand their scientific explanations; nor do they accept or understand the graduate students' enthusiasm for the subject. This challenges the graduate students to reformulate, rephrase and re-explain. The role of the teacher is that of a mentor to the graduate student and as the instructional leader for the classes. The role of the school-based cohort is to provide instructional support and communication across grade levels within a given school. Faculty, engineers and scientists act as consultants to both the graduate students and the teachers.

**Benefits and Goals**

The long term benefits of the developed skills to the graduate student are obvious: mathematics, science and engineering graduate students, the next generation of scientists and engineers, will be able to explain their subject area to the broader population as well as to their own students. This is a skill which is rarely found in the professional engineering and scientific community. The benefits to the elementary school students are also apparent: the participating students are exposed to successful role models in mathematics, science and engineering. The participating teachers benefit from the acquisition of continuing education credits, advancement of their professional knowledge, availability of additional classroom resources and classroom support in the form of a graduate student. The school based cohort benefits through the development of communication and support structures across grade levels within the given school. Faculty, engineers and scientists benefit from the availability of a well-designed outreach program to which they can connect their research efforts. The primary goal of this partnership is to increase the participating teachers’ and students’ knowledge and understanding of mathematics, science and engineering and how these subjects are applied in the world.

**Even and Integrated**

Each year, the Bechtel partnership is adapted to the changing needs of the district, university and participating laboratory. In 2009, the district shifted their curriculum to SBS, eliminating grade levels and grouping students by ability. The participating teachers provided instruction to the faculty and graduate students as to how this change impacts the nature of the classroom and instruction. In 2010, the Adams 50 district adopted Foss kits in all elementary grade levels. Many of our graduate students’ attended Foss training at their assigned school, learning how to embed these materials into the broader program and how to use these kits to illustrate their own research. A local national laboratory, the National Renewable Energy Laboratory, as well as a National Science Foundation Research Center were recruited to further assist in this partnership. Both of these partners focused on renewable energy, resulting in an adoption of some of our materials to reflect a similar focus. Before any changes were made to the program, feedback and support was acquired from the districts’ administration and teachers. As these examples
illustrate, at the broadest level, this partnership’s design and implementation is regularly adapted to meet the needs and requests of the participants. The next section provides a classroom example, illustrating the bond and collaboration that emerges through this partnership at the classroom level.

Classroom Example with Age Appropriate Activities

This section describes a classroom experience of an elementary teacher at Hodgkins Elementary, Ms. Zook, her students, and the graduate student, Megan, all of whom are participating in this partnership. Ms. Zook teaches a multi-age, high achieving class consisting of third through fifth grade students. She believes in experiential learning and a hands-on approach to the instruction of mathematics and science. Her classroom is diverse, and many of her students have language barriers. She finds that experiential learning can be adapted such that it meets the needs of her students, including those that have limited English proficiency. Hodgkins Elementary is considered a “failing” school by the state, as it has not met the annual yearly progress requirements set forth in No Child Left Behind. Ms. Zook was excited to join this partnership, believing that the inclusion of a graduate fellow would help her to create an environment of mathematical and scientific enthusiasm in her classroom as well as increase student performance levels in mathematics and science.

Ms. Zook designs her lessons in a manner that illustrates to students the relationship that exist among mathematics, science and social studies. Given this is an elementary classroom, literacy also continues to be a key focus of instruction. Megan is able to explain to students the relationship of her major, mathematics, to the various instructional units. Together, Ms. Zook and Megan planned the unit described here, which addresses man-made disasters and how these events impact people and the environment. This lesson introduces environmental engineering to the students. Given the demographics of the student population, these students are unlikely to have family members who are engineers and therefore are unlikely to have had previous exposure to the practical applications of engineering to the environment. The complete lesson plan is provided in Appendix A. The students’ learning targets in science and mathematics follow. Science is reflected in numbers 1 through 6, and mathematics in 7 through 11.

By the conclusion of this unit, students will be able to: 1) Differentiate between the basic needs of animals and plants; 2.) Demonstrate how to make observations using simple tools to gather information; 3.) Generate basic questions about the physical world based on observations; 4.) Develop hypotheses based on observations; 5.) Analyze the interrelationships between organisms and components of an ecosystem; 6.) Perform simple experiments to answer scientific questions; 7) Place information onto a data display; 8) Read and interpret pictorial representation of measurement of length, weight, temperature and capacity; 9) Analyze information from data displays; 10) Organize, construct and interpret pictographs; And 11) Create a graphical representation of given data and use it to make a prediction.

The lesson spanned eight days and began with students reading the book Oil Spill: Disaster in the Gulf. This was followed by the viewing of two videos, Black Tears and Innocence Lost (youtube), both addressing the Gulf Oil Spill. On the second day, Megan, the graduate teaching fellow, led a discussion of the Exxon Valdez oil spill, the Duck Spill, the Nike tennis shoe spill,
and the Gulf Oil Spill. This discussion included what happened, how it happened and the methods for clean-up. Additionally, the students were asked to predict where a spill would spread given an ocean current map and point of origin, examples of which are in Appendix B. On the third day, the importance of hydrates and the reasons we use them was discussed as well as the impractical and unlikely potential of removing hydrates from our environment. On day four, the students began to build their own environments using plasticine clay and plastic shoeboxes. These environments were filled with water and later polluted using dirty motor oil. A variety of measurements were taken and mathematically tracked, as is described in Appendix A. Additionally, pictures of students’ environments are provided in Appendix B. Before simulating an oil spill, the students developed a plan and brainstormed methods for cleaning their environments using materials that they would be responsible for bringing to class. The last day of the lesson, Megan led a class discussion on what the students learned from their experiments. How well did their methods of clean-up work? Would their environments be the same after the spill? She also addressed the important role that environmental engineers play in the prevention and clean-up of such events.

Lesson Impact

This lesson impacted 52 students in two classes. The impact was measured using a nine question, open-response, pre- and post-test which assessed students’ knowledge of oil spills. This instrument and example student responses are contained in Appendix B. The first and second classes had pre-test means of 40% and 31% and standard deviations of 16% and 15%, respectively. For the post-test, students average scores increased to 78% and 76% with standard deviations of 19% and 14%, respectively. These results were found to be statistically significant based on paired, one-tailed t-tests, with p-values of \( 5^{10} \) and \( 2^{13} \), respectively. From a quantitative perspective, the students displayed significant growth in their understanding of oil spills and the environmental impact of such events.

There was also qualitative evidence to support student growth in these areas. Sample pre-test responses to the question “In what ways does an oil spill affect humans?” were “It makes us sad” and “It makes us clean it up.” Sample post-test responses to the same question were “It affects humans by people losing their jobs” and “An oil spill affects humans by getting in our food/water, affects our air [sic].” Prior to the lesson, several students did not know there was an oil spill last summer. After the lesson, students were able to discuss the Gulf Oil Spill and its environmental and human impact. The mathematics and science discussed during this unit were directly linked to the district standards through learning targets.

Workshop Impact

During the summer workshops evidence was collected in the form of a pre and post assessment of the participating teachers. All teachers completed the pre and post multiple choice instrument. On average, the teachers responded correctly to 13 of 26 questions on the pretest and 22 of 26 questions on the posttest. This result was found to be statistically significant based on a paired, one-tailed t-test, with a p-value of less than .0001. Self-report instruments provided further support for this result.
Project Emulation

This is a fully developed lesson plan that can be emulated by other classrooms, schools and universities. The materials needed for this lesson are easily available and cost less than $60 total for the classroom. Each classroom was divided into 7 or 8 groups, reducing the costs for the creation of an environment. This lesson plan will be shared with other teachers who are participating in this project through a formal presentation during the 2011 summer workshops.

Overcoming Challenges, Lessons Learned and Successes

The main challenge of this lesson was the demographics of the classroom. Many of the participating students have been raised in poor families and Spanish is their primary language. According to educator Ruby Payne, in generational poverty, the driving forces are survival, entertainment and relationships. Oil spills and engineering are outside the realm of these students’ experience. Some of the students were unaware of the recent oil spill; others did not identify an oil spill as a major concern. Building the simulated environment allowed all students, regardless of language, to participate and learn from the activity.

Class size was also an obstacle. The larger class was more difficult to keep on track than was the smaller class. In one class, student interruptions prevented completing the book, Oil Spill Disaster in the Gulf. The graduate student was continually challenged to engage the interests of this diverse group of learners, an experience that is not common to graduate education.

Summary

In the prior description of this partnership, we have shared the design of the partnership and provided a description of this lesson and its outcomes. A discussion of the specific challenge of language and culture barriers was provided. Lesson emulation was touched upon so that schools with an interest in the lesson plan have a resource. Several of the student environments are shown in the appendix and provide additional examples for emulation. This lesson was designed to be interactive and hands-on in nature and draws on the expertise of the participating teacher, graduate student and faculty. A primary goal of the Bechtel partnership is to disseminate our efforts beyond our current participants; this paper greatly advances our efforts in this area.
Appendix A
Oil Spill Lesson Plan

PURPOSE: For students to understand what oil spills are and how they affect our environment and humans.

SBS SCIENCE LEARNING TARGETS: Students will be able to differentiate between the basic needs of animals and plants; demonstrate how to make observations using simple tools to gather information; generate basic questions about the physical world based on observations; generate hypotheses based on observations; analyze the interrelationships between organisms and components of an ecosystem; and finally, perform a simple experiment to answer a question.

SBS MATH LEARNING TARGETS: Students will be able to place information onto a data display; read and interpret pictorial representation of measurement of length, weight, temperature and capacity; analyze information from data displays; organize, construct and interpret pictographs; and create a graphical representation of given data and use it to make a prediction.

INQUIRY QUESTION: How does an oil spill happen, how are they cleaned up, and what effect do they have on our environment and people?

OBJECTIVES:
1. Students will be able to describe what an oil spill is and how one happens.
2. Students will be able to describe different methods to clean up an oil spill.
3. Students will be able to predict where oil spills will flow given ocean current maps. For higher level students, they can also be taught to use wind current maps as well as ocean current.
4. Students will understand the effects of an oil spill on the environment and humans.
5. Students will be able to clearly communicate and execute a method of cleaning up a miniature oil spill.

TIME: Eight one-hour class periods.

MATERIALS:
1. A plastic shoebox container for each group
2. Plasticine (impermeable) clay
3. Water
4. Dirty motor oil (or vegetable oil that has soaked with felt from marker)
5. Students bring in their own materials that they brainstormed for clean-up
6. Paper towels
7. Trash bags
8. Worksheets
9. Books on oil spills
PREPARATION: Teacher should have good background knowledge of how oil spills occur and methods used to clean them up. Teachers should be aware of student knowledge and limitations and be able to adjust lesson accordingly.

PROCEDURE:

Day 1: Prior to any discussion, give the students the pre-test. Have students fill out a Know/Want to Know/Learned (KWL) chart about oil spills. Read the book Oil Spill Disaster in the Gulf by Scholastic to students. Lead a class discussion about the Exxon-Valdez and BP Gulf oil spills. Include duck spill of 1992 and Nike tennis shoe spill of 1990 because they are also environmental disasters, despite the fact that the children will see them as humorous. Show pictures of the duckie, turtle, beaver and frog tub toys, or if you are lucky enough, show the actual toys to students, and talk about how scientists are using the duck disaster to track ocean currents. Share youtube videos Black Tears and Innocence Lost about the BP Gulf oil spill.

Day 2: Teach class how to use an ocean current map to make predictions on where the oil will travel as it moves through the environment. Students will make predictions where they believe the oil and/or ducks will travel as they are carried by ocean currents using the first few sighting of ducks found after the 1992 spill. They will then compare their predictions to the historic data (e.g. Exxon-Valdez and Duck Spill) to see how accurately they predicted the flow. Afterwards, the students will discuss how oceanographers and engineers use oil spill and ocean current data to hypothesize where oil spills will travel and use that information to place booms and other equipment to assist in clean-up.

Day 3: Lead a class discussion of clean-up efforts and how people help to clean up oil spills. Talk about how sometimes trying to clean and save animals ends up hurting them. Talk about the companies and universities who helped to stop the Gulf oil spill and are still doing research. Talk about how long the Gulf oil spill lasted (87 days) and how oil is still being found in Alaska 20 years after the Exxon-Valdez oil spill. Tell the students that even though the duckies are cute, they are still considered pollution.

Day 4: Show the students the video on hydrates that was shown during the summer workshop. Talk about the role that hydrates played in the Gulf oil spill. Typically students will say that we shouldn’t use oil anymore. Ask the class what ideas they have for other types of energy to use. A lot of students don’t know where energy or electricity comes from. Have the students brainstorm ideas for cleaning up oil spills.

Day 5: Tell the students what they will be doing for the oil spill. Explain about building their environments out of the shoeboxes and clay, and require that their environments have at least four land forms (bay, harbor, mountain, volcano, field, forest, etc.). Students can use “Geographical Terms” map by Rand McNally & Co as an example. Have each student fill out a worksheet describing what materials they will use to clean up their oil spill and how they will be used. Begin building environments.
Day 6: Continue building environments. (This may take more than one day). During math, talk to students about how many oil spills happen on average annually. On average, there were 4 spills per year between 1970 and 1999, and 17 spills per year between 2000 and 2009. Have students calculate the number of oil spills that have happened in their lifetimes by multiplying their age by 17. Assuming an average of 4 spills per year until 2000, have students calculate the number of spills in their teacher’s lifetime. Visually interpret this by using different colored beans of similar size to model the number of oil spills. Place the correct number of beans in a jar, being careful not to mix the different colors. Place the beans representing the spills during the teacher’s lifetime on the bottom and the beans representing the spills during the students’ lifetime on the top. Explain to students that there has been a four-fold increase in the number of oil spills, and ask them to predict how many oil spills would happen in 20 years if there were another four-fold increase. Ask them to predict how many oil spills would happen in their child’s life if there were four-fold increases every 30 years. Students can also make bar graphs representing the number of oil spills in their lifetime, their teacher’s lifetime and the fellow’s lifetime.

Day 7: Prior to the oil spill, the teacher should check that the students brought materials for the clean-up and have a plan in place. The teacher will add water to the environments such that part is underwater and part is above water. The teacher will add oil to the environments and can cause a “storm” by shaking up the shoeboxes. Students must work cooperatively to clean up their spill.

Day 8: What did the students learn? Fill out the “Learned” part of the KWL chart. A fun thing to do at this point is use [www.wordle.net/create](http://www.wordle.net/create) to make a graphic representation of the students’ feedback (see example in appendix B). Discuss with the students if their environments would ever be the same. What are the long range damages of the oil spill? Talk about how duckies are still floating around and are being tracked, and remind the students that oil is still being found from Exxon-Valdez oil spill. Nike shoes are still washing up on shore, too. Read the book *Ducky* by Eve Bunting. Lastly, administer the post-test to the students.

RELATED MATERIALS:

- Oil Spill: Disaster in the Gulf by Scholastic
- Ducky by Eve Bunting
- Oil Spill! by Melvin Berger
- Prince William by Gloria Rand
- Gulf Coast Oil Spill: Poor Little Pelican + A KidReports Photo-documentary by Carole Marsh
- Oil Spills: Damage, Recovery and Prevention (A Save the Earth Book) by Laurence P. Pringle
- Black Tears youtube video
- Innocence Lost youtube video
• “Geographical Terms” map by Rand McNally & Co.
• Ocean Currents Map from http://www.oceanweather.com/data/

REFERENCES


Tossava, Kathy. *Ocean Currents Lesson Plan*. 

Oil Spill Questionnaire

1. What is oil made from?

2. What is an oil spill?

3. How can an oil spill happen?

4. How many oil spills occur on average each year?

5. In what ways does an oil spill affect the environment?

6. In what ways does an oil spill affect humans?

7. What is one way to clean up an oil spill?

8. What makes it difficult to clean up an oil spill?

9. a. How much did it cost to clean up the Exxon-Valdez oil spill?

   b. How much has it cost so far to clean up the BP oil spill?
A spot has been placed where the Rubber Duck Toy Spill took place. Based on the ocean current map predict how the toys would travel. Indicate where you believe the toys would land (water and land) using a marker and larger arrows.

What else might play a role in how the toys travel through the environment?
The Gulf Oil Spill took place in the approximate location of the dot. Based on the ocean current map predict where the oil would flow (water and land). Use larger arrows to show your predictions.

In your group brainstorm ways to stop or slow down the spread of the oil, write your ideas down on the back of this paper. With a brown marker show where you would place your booms or other devices to stop the oil flow.
A spot has been placed where the Exxon Valdez Oil Spill took place. Based on the ocean current map predict where the oil would flow. Indicate where the oil would travel (land and water) using a marker and larger arrows.

What else might play a role in how the oil travels through the environment?

Where would you place booms or build barriers to prevent the oil from traveling further, killing animals, and damaging land. Use a brown marker to show where you would place these items. On the back describe what you would construct to help in this situation.
1. Write down your group’s plan for cleaning up your oil spill. Be detailed about what materials you plan to use and how.

2. Why do you expect your plan to work?
1. Make some observations about the oil in your environment.

2. Does your method for cleaning up your group’s oil spill seem to be working? Why or why not?
Appendix B
Examples of Student Work

This section shows photographs of students as they work on creating their environments as well as cleaning them up.

The image above on the left is of the students’ KWL chart. In the image on the right, students are starting to create their environment using clay and the plastic shoebox.

These images are of students’ environments before (left) and after (right) adding water.
The pictures above are of oil spills before clean-up (left) and during clean-up (right). Several students removed some of their land forms to make clean-up easier. Discussion followed as to whether they could do that in real life.

The image above is of one of the most successful groups to clean-up their oil spill. They used various materials such as q-tips, cotton balls, coffee filters and paper towels. They also had leaves and sticks in their environments, which surprisingly, they were able to clean rather well.
This image is the wordle created from the students “want to know” comments from the KWL chart.
The Gulf Oil Spill took place in the approximate location of the dot. Based on the ocean current map predict where the oil would flow (water and land). Use larger arrows to show your predictions.

In your group brainstorm ways to stop or slow down the spread of the oil, write your ideas down on the back of this paper. With a brown marker show where you would place your boons or other devices to stop the oil flow.
I going to use a boom.
To block the oil from land. Also its important to block oil from animals, reefs, plants, and water.

A boom to block oil from land.
The Gulf Oil Spill took place in the approximate location of the dot. Based on the ocean current map predict where the oil would flow (water and land). Use larger arrows to show your predictions.

In your group brainstorm ways to stop or slow down the spread of the oil, write your ideas down on the back of this paper. With a brown marker show where you would place your boons or other devices to stop the oil flow.
I am using a microb boom to clean up my oil spill. I chose the microb boom because the microbs eat oil and the boom can catch oil.
A spot has been placed where the Exxon Valdez Oil Spill took place. Based on the ocean current map predict where the oil would flow. Indicate where the oil would travel (land and water) using a marker and larger arrows.

What else might play a role in how the oil travels through the environment?

Wind

Where would you place booms or build barriers to prevent the oil from traveling further, killing animals, and damaging land. Use a brown marker to show where you would place these items. On the back describe what you would construct to help in this situation.
My barriers are made out of hair, straw and cotton. I will place these barriers in the western states, Hawaii, a little bit of Russia and Australia.

Picture of barriers
1. Write down your group’s plan for cleaning up your oil spill. Be detailed about what materials you plan to use and how.

   We are going to use bubble gum paper to clean oil. Also, we are going to use paper towels.

2. Why do you expect your plan to work?

   The bubble gum should absorb the oil like paper does. The paper towel will take a lot of oil. Also, the gum paper will take a lot of oil.
Name(s):

1. Make some observations about the oil in your environment.
   The oil is destroying everything and killing animals. It is making everything very dirty. A couple of men have drowned in the oil.

2. Does your method for cleaning up your group's oil spill seem to be working?
   Why or why not? Our method for cleaning worked really good because the gum that was not bad took a lot of oil in. Also, the paper towel sucked a lot of oil in. The bubble gum that was chewed didn't work too bad because it didn't take oil in.
1. Write down your group’s plan for cleaning up your oil spill. Be detailed about what materials you plan to use and how.

   Our plan of cleaning is putting sponges in the environment to clean it and scoop it up with a sack in or cup.

2. Why do you expect your plan to work?

   I expect our plan to work because the sack has holes and the oil won't go through but the water will.
1. Make some observations about the oil in your environment.
   The oil is spreading all around the water and polluting it.

2. Does your method for cleaning up your group’s oil spill seem to be working? Why or why not?
   Our method for cleaning our oil spill did work. It worked because when we put it in the sock only the water came out.
1. Write down your group’s plan for cleaning up your oil spill. Be detailed about what materials you plan to use and how.

   We are going to bring a sponge to skim the top or bring hair. What we are going to skim the top off the oil & the water before the oil sinks. The sponge is an absorbent material.

2. Why do you expect your plan to work?

   I expect our plan to work because the sponge is absorbent material. So the sponge will absorb the oil on the top of the water.
1. Make some observations about the oil in your environment.

   Our ... When the oil was put in Me
   shook it and now all of our
   animals sea life had got oil
   on them. The land is still safe.
   Before it was shook the oil
   spread so fast. Also it
   started bubbling a little. The oil went
   to the side and edges of
   the land. It collects onto the
   edges. Our fish died.

2. Does your method for cleaning up your group’s oil spill seem to be working? Why or why not?

   Our method worked because
   some of our clay didn’t get ruined
   and our land had survived.
   It also didn’t work because
   our fish died. Some of our
   clay had come off.
   But our oil is out!
Lifetime of Oil Spills

Years of Oil Spills

- 1904-1912
- 1970-2004
- 2008
- 2010
- N.A.
Lifetime of Oil Spills

Years of oil spills

# of oil spills
PRETEST

Oil Spill Questionnaire

1. What is oil made from?
   - molters

2. What is an oil spill?
   - it is oil spread somewhere because...

3. How can an oil spill happen?
   - by boats?

4. How many oil spills occur on average each year?
   - 1-3

5. In what ways does an oil spill affect the environment?
   - it can destroy our environment, how?

6. In what ways does an oil spill affect humans?
   - by going in to our environment, and...

7. What is one way to clean up an oil spill?
   - take some oil out, how?

8. What makes it difficult to clean up an oil spill?
   - it is dig., ?

9. a. How much did it cost to clean up the Exxon-Valdez oil spill?
   - millions, more.

   b. How much has it cost so far to clean up the BP oil spill?
   - millions
1. What is oil made from?
   - It is made of dirt and yucky things

2. What is an oil spill? An oil spill is oil spilt in a ocean or another place.
   - because...

3. How can an oil spill happen? An oil spill can happen by a boat hitting a
   - rock and oil spills out of the boat into the ocean.

4. How many oil spills occur on average each year?
   - It spills 2 or 3 times a year.

5. In what ways does an oil spill affect the environment? It effects the environment because
   - it kills animals and plants.

6. In what ways does an oil spill affect humans? It can effect humans because if you are
   - on a boat and it kicks the rock and you can fall in the ocean and
     - travel by boat and you can get stuck in the oil spill.

7. What is one way to clean up an oil spill?
   - Get a big crane and get the oil out.

8. What makes it difficult to clean up an oil spill?
   - It is hard to get all the oil out after it already happened.

9. a. How much did it cost to clean up the Exxon-Valdez oil spill?
   - It cost a lot of money.

   b. How much has it cost so far to clean up the BP oil spill?
   - (I don't know)
PRETEST

Oil Spill Questionnaire

1. What is oil made from?
   - It is made from the oil in the cars engine. [X]

2. What is an oil spill?
   - An oil spill is a leak of oil spilled into the ocean or land!

3. How can an oil spill happen?
   - An oil spill can happen when an oil company gets a leak in a pipe or somewhere.

4. How many spills occur on average each year?
   - About 1,000 [X]

5. In what ways does an oil spill affect the environment?
   - The oil spill affects the environment by killing the animal's habitats and the animals homes & food.

6. In what ways does an oil spill affect humans?
   - I am not sure how the oil spill affects humans.

7. What is one way to clean up an oil spill?
   - I also am not sure I know a way to clean up an oil spill.

8. What makes it difficult to clean up an oil spill?
   - It is difficult because oil spills are hard to clean.

9. a. How much did it cost to clean up the Exxon-Valdez oil spill?
    - I am not sure, about 5,000 [X]

   b. How much has it cost so far to clean up the BP oil spill?
    - I am not sure, about 5,000.
POST TEST

Oil Spill Questionnaire

1. What is oil made from?
   Oil is made from fossilized plants or animals.

2. What is an oil spill?
   An oil spill is when oil spreads on land or seas that might be caused by people.

3. How can an oil spill happen?
   An oil spill can happen when a machine filled with oil explodes.

4. How many oil spills occur on average each year?
   17 oil spills can occur on average each year.

5. In what ways does an oil spill affect the environment?
   An oil spill affects the environment by killing animals, people, or others.

6. In what ways does an oil spill affect humans?
   It can affect humans by making fishermen lose their jobs.

7. What is one way to clean up an oil spill?
   One way to clean an oil spill is by using booms.

8. What makes it difficult to clean up an oil spill?
   It is difficult because it is kind of hard to move through oil.

9. a. How much did it cost to clean up the Exxon-Valdez oil spill?
    I cost about 21 billion dollars to clean up the Exxon-Valdez oil spill.

   b. How much has it cost so far to clean up the BP oil spill?
    It has cost about 41.6 billion dollars to clean it up so far.
POST TEST

Oil Spill Questionnaire

1. What is oil made from?
   Oil is made from all kinds of dead animals.

2. What is an oil spill?
   An oil spill is an accidental release from the human activity that oil is can explode.

3. How can an oil spill happen?
   A place where oil is can explode.

4. How many oil spills occur on average each year?
   On average 17 oil spills would happen each year.

5. In what ways does an oil spill affect the environment?
   Oil spills kill animals, destroy coral and it can hurt our land.

6. In what ways does an oil spill affect humans?
   Oil spills can affect people by affecting them lose their job.

7. What is one way to clean up an oil spill?
   You can clean up an oil spill with a boom and a filter.

8. What makes it difficult to clean up an oil spill?
   There is too much oil to clean up.

9. a. How much did it cost to clean up the Exxon-Valdez oil spill?
   On average $2.4 billion.

   b. How much has it cost so far to clean up the BP oil spill?
   BP on average $11.6 billion.
Overview of the Instructional Model

*Bedroom Design* is an engineering design activity developed by a partnership between middle school teachers in New York, and the Hofstra University Center for Technological Literacy for middle school Engineering and Technology Education (ETE). The curriculum is underpinned by a “hybrid” instructional model that has the potential to transform instruction in ETE. The model preserves the hands-on physical laboratory activity that has engaged generations of students, but incorporates an IT-based engineering design approach that will accelerate technology education’s transition to a contemporary STEM-based discipline. The hybrid model integrates both screen-based 3D simulation and real-world physical modeling into middle school engineering and technology education programs.

The model expands the responsibility of engineering and technology educators to reinforce core disciplinary concepts (particularly middle school mathematics) within technological contexts and includes three components that can redefine the way engineering and technology education instruction is conceptualized:

1. Infusion of core disciplinary concepts (i.e., grade-related mathematics) into ETE instruction.
2. Use of STEM teacher teams to collaboratively plan, assess, and revise instructional approaches.
3. Use of an “informed design” approach to instruction that leads students to develop understanding before they engage in design activity.

*Note:* In this case, the hybrid model used Google SketchUp (GSU), a 3D modeling program available at no cost from Google, followed by hands-on physical modeling of the planned bedroom and reflection time.

A guide for instructors and workbook with student materials can be downloaded from the Hofstra CTL Web site at [www.hofstra.edu/Academics/Colleges/SOEAHS/CTL/ITEA/index.html](http://www.hofstra.edu/Academics/Colleges/SOEAHS/CTL/ITEA/index.html). For further information, contact Chris Malanga (Riverhead Middle School) at chris.malanga@riverhead.net or Michael Hacker (Hofstra University) at mhacker@nycap.rr.com.
Problem Situation

You are moving to a house that is being built for you. The architect who is working on the project needs information regarding your lifestyle to determine the best design for your bedroom. It can be a dream bedroom. The budget is $27,500 for a rectangular bedroom with a minimum area of 120 square feet. However, the budget increases to $30,000 for a nonrectangular bedroom with the same minimum area.

The Design Challenge

You and your teammates will design a furnished bedroom. You will build virtual and actual scale models of your bedroom, with furnishings.

Design Specifications and Constraints

To solve the problem, your design must meet the following specifications and constraints:

- The window area must be equal to at least 20% of the floor area.
- The minimum room size is 120 square feet. The minimum height of all ceilings is 8 feet and the maximum is 12 feet.
- The bedroom will have two outside walls and two interior walls. In both models one interior wall can be removed for easy visualization of the design.
- The budget is $27,500 for a rectangular bedroom and $30,000 for a nonrectangular bedroom.
- The cost of basic construction is estimated at $150 per square foot of floor area

Focus on Engineering

An issue commonly found in middle school design activities, is that students focus more on product design than on mathematics-based engineering design. The bedroom design challenge specifically integrates age-appropriate mathematical analysis and modeling with engineering thinking and engineering design methodologies into the student activity. The mathematics in this activity was explicitly related to middle school mathematics standards.

Additionally, it is quite often the case that trial-and-error problem solving (gadgetering) characterizes design activity in middle and high school classrooms. Trial-and-error problem solving uses up a great deal of class time and the focus is normally on the end result, rather than on the learning. A uniqueness of this project is that it uses an “informed design” approach that provides just-in-time knowledge building as a prelude to design.

Informed design is a validated design pedagogy developed through NSF projects conducted by the Hofstra CTL. It melds guided inquiry with moderately open-ended design and lead students to develop conceptual understanding before they begin designing, but after they have been introduced to the main challenge. In an informed design activity, students develop their STEM understanding (they will inform their STEM knowledge and skill base) by completing a series of
short, focused tasks called Knowledge and Skill Builders (KSBs) before they start designing. Seven Knowledge and Skill Builders are provided within the Student Packet (the complete packet is available upon request). These include the following:

**Math-related KSBs**

- **KSB 1: Geometric Shapes**
- **KSB 2: Factoring**
- **KSB 3: Percentage**
- **KSB 4: Mathematics of Scale**
- **KSB 5: Mathematical Nets**
- **KSB 6: Spreadsheets and Pricing Information**

**K-12 Role in Partnership**

The Bedroom Design unit conveys important middle level ideas in mathematics and technology education. As the unit and embedded activities and lessons were developed by New York State teachers, key ideas are driven by the New York State Standards for Mathematics and Technology Education. These standards are highly correlated to the national (ITEA) Standards for Technological Literacy; and the NCTM Standards for School Mathematics.

The Bedroom Design unit was pilot tested with 59 students during the period between 2007 and 2010. It was field tested by 35 teachers with over 700 students using an experimental and control group protocol. The national field test was cosponsored by the International Technology Education Association (ITEA).

**University Role in Partnership**

The Hofstra CTL is co-directed by David Burghardt and Michael Hacker. The mission of the Center is to promote and support the improvement of STEM literacy for K-16 students and faculty. Since 1992, the Center has conducted eight large-scale NSF projects largely focused on Engineering and Technology Education reform. This project resulted from an NSF Math/Science Partnership project (MSTP), Grant # 0314910.

Bedroom design was conceptualized by the CTL co-directors; the initial engineering design challenge and concept was developed by them and a set of preliminary KSBs were presented to the partner teachers during a professional development workshop. The teachers, particularly Mr. Chris Malanga from the Riverhead NY Schools (a technology teacher and a mechanical engineer) worked with university faculty to refine the materials. Teachers then field tested the materials with classes. During the entire process, faculty provided technical and pedagogical support to teachers in developing the final version of Bedroom Design. The formal research study
Partnership Structure and Goals

During the summer of 2008, 15 New York State middle school Technology Education teachers attended an eight-day workshop for implementing a math-infused Bedroom Design activity co-developed by Hofstra faculty and lead teachers who participated in the NSF-funded Math Science Technology Education Partnership [MSTP] project. Teachers were introduced to the Bedroom Design curriculum, the program’s “hybrid modeling” approach to design, and to ways of supporting middle school students’ use of mathematics when designing model bedrooms, including those approaches that math teachers themselves use when introducing the mathematical concepts and problem-solving strategies to students.

The partnership was enhanced though collaboration with the International Technology and Engineering Educators Association (ITEEA), the professional association representing ETE teachers in the U.S. The ITEEA and Hofstra co-sponsored a professional development workshop at the March 2008 ITEA annual conference in Louisville, KY that introduced 20 additional teachers from 16 states to the program. All of the teachers field-tested the unit with middle school students during the spring 2008 semester.

The goals of the partnership were:

1. To develop a model that is driven by infusion of core disciplinary concepts into ETE instruction.
2. To encourage STEM teacher teams to collaboratively plan, assess, and revise instruction.
3. To use an “informed design” approach to instruction that leads students to develop understanding before they engage in design activity.
4. To establish a hybrid instructional model that integrates both screen-based 3D simulation and real-world physical modeling into middle school engineering and technology education programs.

<table>
<thead>
<tr>
<th>Challenge Encountered</th>
<th>Strategies Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Align ETE math pedagogy with that used in math classes.</td>
<td>Promoted collaboration as members of STEM teacher teams. Engaged math education specialists.</td>
</tr>
<tr>
<td>Embed a pedagogical design process instead of the more typical trial-and-error designing.</td>
<td>Developed an “informed design” pedagogy that relied on short “knowledge and skill builder” tasks to inform students of requisite knowledge prior to designing.</td>
</tr>
<tr>
<td>Enhancing Math Pedagogical Content Knowledge in ETE Teachers</td>
<td>Supported ETE teachers by facilitating regular conversations with math teacher-experts who modeled good math pedagogy.</td>
</tr>
</tbody>
</table>

Table 1. Challenges encountered and strategies used to overcome them
Explanation of Successes and Lessons Learned

After teaching the BD unit, TE teachers felt more confident and capable in using math KSBs with their classes. They described ways they were doing similar work with other design tasks they teach and were supporting other colleagues in similar endeavors with other classes. The data also suggest that programs should work harder to support and sustain math-ETE teacher relationships during unit implementation, a coordination effort that can be quite difficult. Finding included:

Exemplary materials themselves will not result in improved teaching and learning; professional development must accompany these materials.

The development of exemplary teaching materials requires not only significant teacher enhancement, but also the involvement and refinement of materials by curriculum and content experts.

To become exemplary, lessons must be revised after being informed by analysis of student work and evidence of student understanding.

Attention needs to be paid to the ways in which the content is being taught. Exemplary mathematics-infused design curricula require that pedagogical approaches similar to those used in mathematics classes should be cultivated to reinforce earlier math learning.

Strengths of all partners must be respected, where “status differential” is minimized. University faculty members are often perceived by school personnel as experts, even pedagogical experts, when in fact, their expertise may be limited to disciplinary knowledge and logistical leadership. Expertise in working with the realities of classroom teaching need to be acknowledged.

Research Results - Students’ Learning of Mathematics in Designing Model Bedrooms

While this paper’s main focus has been on key features of the Bedroom Design project and the impact of the program on teachers’ thinking and practice in the classroom, students’ learning of mathematics while doing the bedroom design unit was also studied. Teachers administered a pre- and post-test on targeted math ideas found on the high-stakes tests that students in New York state currently take every year from third to eighth grade. Identical items were used these two tests, but their sequence of presentation were altered to avoid order effects.
Pre-test scores for students’ mathematics knowledge showed a wide range of starting points: the mean pre-test score of 46.5 had a range of 40 points, while the post-tests averaged 51.5 points, and ranged just under 39 points (SE=15.16). There was thus a net improvement for all students of 5 points in the 100-point math test developed and administered by the project. A few positive correlations of statistical significance were noted between students’ math scores and events noted in classroom teaching. Improvement in students post-test scores and teachers’ self-reported confidence that students could do the mathematics was positively correlated [Pearson Correlation =+.711, Sig.(2-tailed)=.006]. Also, improvements in students’ scores and the teachers’ implementation of the bedroom design unit with high fidelity was also positively correlated [Pearson Correlation =+.588, Sig.(2-tailed)=.035]. Perhaps most importantly, a strong positive correlation was seen between teachers’ own understanding of the math concepts and students’ post-implementation math scores [Pearson Correlation =+.564, Sig.(2-tailed)=.014].
Examples of Student Work
HIGH SCHOOL WINNER

DREAM: Lessons Learned from a Pre-Engineering Outreach Program Implemented in Underserved Urban High Schools

Tim Johnson, Stephen F. Austin High School, Houston, TX
Brent C. Houchens, Rice University, Houston, TX

Abstract

The DREAM-Achievement through Mentorship program (dream.rice.edu) encourages underrepresented and underserved high school mentees to pursue STEM degrees by introducing them to engineering via design projects. Long-term mentoring relationships are established to promote the personal and academic growth of the mentees. Mentors are comprised primarily of undergraduate engineering students from Rice University. These mentors volunteer their time and serve as project managers to the design teams. Designs focus on engineering concepts and reinforce pre-engineering (especially physics and mathematics) education. Teams must complete some design task related to fundamental concepts such as gravitational acceleration, potential energy, kinetic energy, static loading, dynamics and buoyancy. Projects introduce the engineering design process and include brainstorming, design, testing and iteration. More importantly, mentors dispel incorrect perceptions about the cost of attending college and introduce the idea of long-term earning potential. Significant increases are observed in mentees in both interest in engineering and intuition for pre-engineering concepts.

Overview

DREAM, now implemented at three inner-city high schools in Houston, Texas, was founded in 2007 as a partnership between Tim Johnson, Chair of the Science Department at Stephen F. Austin High School, and Brent C. Houchens, assistant professor of mechanical engineering at Rice University. Austin High School (AHS) is a Title I school comprised of 1920 students. In the 2008-2009 academic year, 91% of AHS students received reduced price or free lunch. AHS student demographics are 95% Hispanic/Latino, 4% African-American and 1% Caucasian. Engineering design projects are carried out in teams of 2-4 mentees, with volunteer undergraduate engineering mentors serving as project managers. Mentors are encouraged to discuss engineering careers, college life and financial aid with their mentees. This occurs naturally as trust builds between the mentees and mentor. Approximately 20 mentors (4 each day) travel to Austin High School five days a week, 8 weeks a semester, and meet with their mentees in Tim Johnson’s science classroom.

On DREAM Day, 30-40 Austin High School mentees travel to Rice University to build and demonstrate their designs, tour labs and engineering design facilities, attend financial aid, admissions and physics lectures, and participate in a panel discussion with mentors. Implementations of DREAM also take place at Chavez High School (CHS) and KIPP Houston High School (KIPP).
Literature Review

DREAM mentors volunteer their time, building trust with mentees and nurturing a community invested in mentee success. They do not receive pay or academic credit. This volunteer approach has been shown effective in outreach and service learning activities (Clary et al. 1998). Furthermore, learning is enhanced through the use of hands-on active-learning projects (Bayles & Monterastelli 2009). While there are design criteria and design goals in DREAM projects, the focus is on the engineering process and teamwork, which aids in retaining female mentees (Seymour 1995). At AHS and KIPP, where mentees self-select, between 45% and 48% of the mentees are female. At AHS DREAM is a five day per week, afterschool activity in which participation is completely voluntary. Some mentees attend the required one session per week, but more than half of the mentees attend at least twice a week. Several spend up to four afternoons per week participating in DREAM.

Research Questions

Mentee Perceptions of Engineering, College Admissions and Financial Aid

Mentee perceptions are determined using Perception and Environment Surveys (PES), administered each semester, pre-DREAM and on DREAM Day at the end of the program. Surveys focus on mentees’ interest in studying engineering, and their understanding of college admissions standards and financial aid. Mentors are encouraged to discuss financial aid, no-loan policies, and long-term earning potential associated with engineering degrees, and PES help measure how effectively that information is disseminated. The current mentee PES (and a mentor survey) can be found in the appendices in (Castilleja et al. 2010).

Mentee Pre-engineering and Mathematics Learning Outcomes

Mentee learning outcomes are measured through a series of two Inventories, also administered pre-DREAM and on DREAM Day. Intuition Inventories (II) present physical scenarios and ask mentees to predict the outcome. Pre-engineering Concept Inventories (PCI) additionally require the mentees to provide algebraic expressions to describe these physical situations, and to then evaluate these expressions. The DREAM design projects allow for introduction of engineering concepts such as static loading of structures, buoyancy, and ballistic flight. II and PCI samples of can be found in the appendices in (Campo et al. 2009) and (Goza et al. 2010).

Results

Mentee Perceptions

The most compelling findings are those from Austin High School, where nearly 4 years of data has tracked many mentees. Survey findings include improved mentee understanding of what an engineer does. Over three semesters ending in fall 2008, AHS mentees demonstrating a good or excellent understanding of what engineers do increased from less than 3% to 44% (Campo et al. 2009). A high level of interest in studying engineering has been observed at Austin High School. In fall 2009, seven of eight 12th graders that were long-time DREAM mentees indicated a desire to study engineering in college. All eight were accepted into four year universities, with five
currently studying in math, engineering or science fields. The influence of DREAM must be significant in these outcomes as there is no pre-engineering curriculum at Austin High School.

*Mentee Learning Outcomes*

Mentees demonstrate significant gains in engineering intuition as measured via IIIs. Collection of this data has lead to several programmatic enhancements over the years. As an example, data from the spring 2009 II lead to the creation of mini-lectures, now used throughout the program. This data, shown in Figure 1, demonstrates that mentees’ understanding of Questions 1 and 3 improved greatly at all three schools from pre-DREAM to DREAM Day. These questions focused on the concepts of invariance of gravitational acceleration (Q1) and decomposition of horizontal and vertical motion (Q3). Question 1 involved the classic dropping of two objects of the same size and shape, but different densities. Not surprisingly, most mentees incorrectly predicted that the denser object would fall faster in pre-DREAM testing. Question 2 involved a higher order concept, that of initial velocity. In the pre-DREAM II, more than 50% of all mentees correctly understood that throwing an object down would result in it hitting the ground faster than if it was simply dropped. Throughout the semester, at all schools, the concept of invariance of gravitational acceleration was highlighted through discussions in groups and through demonstrations on DREAM Day. This proved effective as demonstrated by the significant increase in correct answers to Q1. However, at CHS and KIPP, many mentees incorrectly applied what they had learned to the case with a nonzero initial velocity (Q2), reducing the number of correct answers. The only identifiable significant difference between the mentoring at AHS and the other two schools was in total contact hours. Because most mentees at AHS come more than once per week, mentors have time to both complete the project and hold additional informal discussion sections. Mentors discussed the higher order concept of nonzero initial velocity with AHS mentees, hence correct responses by AHS mentees increased for all questions on DREAM Day. Control data from KIPP verifies that these results are attributable to participation in DREAM, and that mentees retain the knowledge several weeks after the program (Houchens et al. 2010). As a result of these findings, the overall length of the program was increased to 8 weeks at all schools, and mini-lectures are now given by mentors before each work day to teach, and then reinforce the engineering concepts involved in the project.

![Figure 1: Correct pre and DREAM Day responses to the three II questions, spring 2009 (Houchens et al, 2010).](image-url)
Challenges and Strategies

Even before DREAM was formalized in 2007, challenges were identified. The first attempts to mentor at AHS were implemented through assisting students with science fair projects in fall 2006, and the introduction of a mentoring program in spring 2007. The mentoring program had no other goal or structure, and it quickly degenerated into a tutoring program. While this was still useful, it was clearly not sufficient to encourage AHS students to go to college, and certainly did not promote engineering. Furthermore, students only attended when they needed tutoring, resulting in unpredictable participation week-to-week. The issue of retention was addressed by switching the focus to the design project. This caught mentees attention, and required the consistent participation necessary for real mentoring to occur. With high contact hours (over 500 mentee contact hours each semester at AHS) there is sufficient time to convey good, accurate information about college admissions, financial aid and engineering careers through casual conversation between mentors and mentees. Consistency is critical, and given enough contact hours, mentees can be convinced that they can overcome the challenges they face in going to college and even studying engineering.

The next challenge is visibility. DREAM is announced by science teachers in their classrooms at AHS to help recruit mentees. It should be noted here that all types of students are recruited, not just the top performers. As a result, high, average and low achieving students are roughly equally represented in DREAM at AHS. Interestingly, what has become apparent is that mentees are the best recruiters of more mentees. Older brothers and sisters often recruit their younger siblings. Girls are particularly effective at recruiting other girls to the program. Mentees that are new to the program react positively to learning that mentors are volunteers, and this dedication spreads to the mentees. On the whole, the public relation aspect of DREAM at AHS has finally been taken up by the mentees themselves, but this took approximately 3 years to establish. This is most notably evident from a recent gathering for a yearbook photo of DREAM mentees. This photo was initiated by the mentees who want the program to be featured in the yearbook, despite the fact that it is not an officially sponsored school club.

Perhaps the most significant challenge is follow through. Even when mentees are armed with good information and strategies for success, overcoming the culture of a “typical” inner-city public school is a major challenge. Going on to college is a major challenge for Austin High School students. Many students at AHS struggle with the college application process and often miss deadlines and application requirements due to limited counseling or familiarity with the process. About 50% of the graduating class go to college but that number could and should be higher. To overcome this we have implemented intensive college preparation sessions for mentees, starting in the second semester of their 11th grade year and continuing throughout their 12th grade year. This includes a summer writing workshop with a focus on college application essays. In fall 2010 mentors literally sat down with mentees and helped them fill out the Texas Common Application and the FAFSA. Mentees often send mentors their essays by email to get comments and suggestions.

We have also identified a few unresolved challenges. Despite efforts to introduce cost analysis into our design process, these have proven neither interesting or effective. Also, it is surprisingly difficult to convince mentees to sketch their designs, though the rigor associated with mini-lectures has improved this aspect. At AHS it is much more difficult to attract a consistent pool
of 9th and 10th graders as compared to 11th and 12th graders. Finally and most importantly, there is still a “gap of desire” between most mentees and the reality of achieving an engineering degree. While we focus on both long-term earning potential and the enjoyment of engineering, it is still an open question as to whether mentees will have the perseverance to take the most difficult high school classes so they are prepared for college, and then whether they will have the perseverance to succeed in an engineering degree program. Here again is a significant struggle to overcome the culture of a high school where most students don’t understand the value of education. In the future we will ask mentors to be more honest about how hard they had to work in high school and how hard they currently work in college. Our mentors are not all A+ students, and many have to struggle in their engineering classes. Often it is more about effort than talent, and this needs to be conveyed to the mentees.

Fortunately, it seems with consistent, long-duration mentoring, the mentees can be instilled with this desire to pursue engineering. Furthermore, raising expectations seems to have a positive impact – namely the mentees rise to the level that is expected of them. This has been most apparent with the introduction of mini-lectures. Often the mentors are presenting concepts that would typically be seen in a sophomore level engineering course (for example, stress and strain). Nonetheless, the mentees seem to enjoy the higher level concepts the most – even if they don’t fully understand them, they try. This was a surprise, but certainly a pleasant one. Inherent here is a bit of competitiveness – mentees want to be able to speak intelligently with their mentors. Thus, adding rigor does appear to translate to improved effort on the part of the mentees, and the program is consistently rewarded when the mentees are challenged.

**Successes and Lessons Learned**

Trust is key to the success of DREAM, and this trust is bolstered by the volunteer nature of the program. DREAM has supported other program findings that design projects are effective for introducing engineering and for teaching pre-engineering concepts. A further success is that it is surprisingly easy to find volunteer mentors – in fact in fall 2010 the logistics of getting all of those who wanted to mentor to the schools proved the most difficult part of running the program. Even given the volunteer nature of DREAM, mentor retention rate hovers around 80% semester-to-semester. When mentors leave the program it is usually because they have undertaken significant on-campus commitments, not because they are dissatisfied with their experience.

It is unclear if this is critical, but not surprisingly it seems that high participation rates by women and underrepresented mentors aids in relating to the mentees. Approximately a third of DREAM mentors are women, and more than half are from underrepresented groups. In DREAM, mentees observe a diverse group of mentors that function with a singular goal.

It is important, maybe even essential, to have real content, and even engineering level rigor in outreach programs. The higher level the concept, the more the mentees listen and the harder they try. In the current cantilever design, mentees are even starting to use the ideas from the mini-lectures in their designs. Even better, this change came about as the result of research on the effectiveness of the program. Without investigating the outcomes we would not have suspected how important this formal component could be in an informal program.
Other lessons we have learned may seem obvious. First, from the university perspective, a dedicated teacher is invaluable. Support of administration is great and needed, but nothing can replace the effectiveness of a great teacher. Second, every school is different. On paper, AHS and CHS look very similar. In reality, DREAM functions in a very different way at all three schools, and this flexibility needs to be built into the outreach program if there is hope for scaling and replication. Third, it is important to take time to reflect, and collect and analyze data. It is a hard habit to form, but most of the good ideas in DREAM have come out of a combination of weekly Head Mentor meetings, and involvement of the Head Mentors in research (all publication have had co-authorship from Head Mentors). Finally, the more contact time between mentors and mentees, the better. This is especially true if the school does not have a pre-college culture. Every interaction with a college mentor helps to undo the indifference toward and misconceptions about higher education.

References


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