AC 2007-777: GK-12 ENGINEERING WORKSHOP FOR SCIENCE AND MATH TEACHERS

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GK-12 Engineering Workshop for Science and Math Teachers

Abstract

This paper describes the implementation and outcomes of a summer workshop for middle school mathematics and science teachers. The focus was on engineering-oriented activities that integrated mathematics and science concepts. The paper describes four such activities: Forces and Math, Pendulums and Graphing, Water Rocket Design and Analysis, and Yogurt Cup Speakers. The summer workshop was the culminating event for a cohort of engineering graduate students supported by the National Science Foundation's Graduate Teaching Fellows in K-12 Education (GK-12) program. The workshop activities were developed by the GK-12 Fellows during the school year and tested in their Teacher Partners' classrooms. The activities were designed to integrate math and science learning through real-life problems. Seventy-three science and math teachers from forty-six schools participated in the workshop.

Information available to report on outcomes of the workshop was obtained from an exit survey administered to the participating teachers. An interesting finding is that the math teachers strongly agreed that the activities were applicable to math and improved their ability to teach math, but the science teachers were less positive about the math content of the activities. An opposite trend was observed for the questions about science. The science teachers strongly agreed that the activities were applicable to science and improved their ability to teach science, but the math teachers were less positive about the science. The two types of teachers performed the exact same activities at the exact same time, and usually in a small group that contained both math and science teachers, yet perceived the workshop differently. This may be interpreted that because the workshop activities used engineering problems to integrate math and science concepts, the math teachers thought it was a good math workshop and the science teachers thought it was a good science workshop. This finding could have implications for future in-service and pre-service teacher professional development efforts.

Background

The Graduate Teaching Fellows in K-12 Education (GK-12) program provides support and training to graduate students in science, technology, engineering, and mathematics (STEM) disciplines that allow them to build partnerships with local K-12 schools, enhance STEM instruction, and improve student learning of STEM concepts.[1] At this university, the Fellows are partnered with a science or math teacher two days a week during the school year. The Fellows also enroll in a one hour graduate level course focused on teaching strategies. They spend 10 hours working in the classroom per week, 1 hour in planning with the teacher-partner, and 5 hours in activity preparation.

Each summer, our GK-12 program culminates with a workshop for middle school math and science teachers. There has been research focused on and related to professional development through engineering, science, and math workshops for teachers[2, 3, 4, 5, 6], but few report outcomes based on participant's subject area. This paper aims to describe the implementation and investigate the outcomes of an engineering workshop, while considering the participants classroom subjects.

Institute Overview

The culminating component of our GK-12 program is the annual Summer Institute for Teachers. The goal of this workshop is to extend the benefits of the Teacher-Partner program to reach additional teachers across the state and to enhance their abilities to use engineering related educational materials to teach science and mathematics. The institute is unique in that it is planned and led by GK-12 Fellows. Four 1-day workshops called "The GK-12 Institute for Teachers: Standards-Based Science, Math, and Engineering Activities for Grades 6-9" were hosted in the summer of 2005. During this year, the Fellows were two Mechanical Engineering graduate students, one White male and one Hispanic female. Each GK-12 Fellow selected their best activities from the school year and coordinated with the other fellows to develop lesson plans and plan the institute. Teachers participating in the institute received: 1) recertification credit, 2) a kit containing materials necessary to use the hands-on activities, 3) a notebook of lesson plans with identified correlations to the State Educational Standards, and 4) a participation stipend to cover personal expenses. All activities are based on the hands-on Learning Cycle model of teaching and learning and are correlated to the state Math and Science standards. Teachers attending the Institute learned to conduct the activities by 1) hearing a brief introduction to the objectives of the activity, 2) conducting the activity and 3) discussing how to implement the activity in their individual classrooms. Four activates were chosen for the Institute discussed in the paper, with math and science teachers in mind: Forces and Math, Pendulums and Graphing, Water Rocket Design and Analysis, and Yogurt Cup Speakers. The workshop activities were taught as 'engineering' activities and were not aimed specifically at math or science teachers. The activities are briefly described below; full lesson plans are included as Appendices A-D, respectively.

Forces and Math. The 'Forces and Math'[9] activity explores loads and reaction forces. In addition, the activity can be used to practice graphing experimental data, and/or to introduce the mathematical concepts of slope and intercept of a line. The experimental setup requires a wooden 2x4 beam set on top of two scales. By standing on the beam, a student will act as the load. The experiment is conducted by the student applying loads at different locations by moving along the length of the beam. The students record the exact position of the applied load and the reaction forces measured by the scales at each end of the beam. In addition, students analyze the experiment data with the use of a chart and a table and model linear equations to describe relationships between independent and dependent variables.

Pendulum Challenge. The 'Pendulum Challenge' uses pendulums to show energy transfer, teach experiment design, and to illustrate relationships between variables. The lesson begins with a discrepant event and a short discussion of pendulums and energy. Students are divided into groups and given materials (string, cups, tape, etc) to construct a pendulum of their own. Each group then hangs the pendulum from a doorway or desk and fills it with a few marbles to give it some weight. The students are then challenged to get the pendulum to swing back and forth in 1 second; this is called the period of a pendulum. Students create a data table and experiment with the variables of weight and length in order to achieve the desired period. The data and the relationship between the variables are discussed. Students are then introduced to the formula for the period of a pendulum; which supports the finding that the length variable is directly proportional to the period.

Water Rocket Design. This activity uses water rockets to illustrate the relationship between force and mass. In addition, the angle of the rockets can be measured with an altimeter and converted to height using similar triangles. The bottles can also be fitted with fins to add to the rocket's stability. Two-Liter bottles are filled with varying amounts of water and placed on a rocket launcher. Because the bottles are filled with different amounts of water, they are expected to perform differently. Students predict the rankings of the Bottle Rockets and create a table to record their data. The air in the bottles is pressurized by pumping air into the bottle. When the bottle is released from the launching pad the pressure in the air forces the water out of the bottle. Using Newton's 2^{nd} law, the accelerating mass of water causes a force on the bottle in the opposite direction causing the bottle to 'launch.' Students record the maximum angle of the rocket with an altimeter and use similar triangles to convert this angle measurement to height. They can then plot the data and see if they see which volume of water reaches the greatest height.

Yogurt Cup Speakers. This activity[10] illustrates the role of electricity and magnetism in a real life application of a speaker. Students create and experiment with an electromagnet using wire and batteries. They then create a speaker using the coil, by attaching it and magnet to a yogurt container. By running wires off the coil, students are able to hook the speaker up to a radio and listen. The activity can be extended to include equations for advanced students. Students may vary the amount of current and monitor the changes in the speaker's movement. They should then check if the results match what is expected using the equation of a coil.

Assessment Methodology

In order to aid in the assessment of program outcomes, the Institute participants were asked to fill out an evaluation survey at the conclusion of the Institute. The participant survey was developed based on previous post-institute surveys, but also included specific questions regarding the degree to which each activity is appropriate for the teacher's classroom setting. The survey was divided into four main sections 1) demographics, 2) general workshop-related questions, 3) degree to which activities are appropriate for your classroom setting, 4) open ended questions. The second and third sections utilized a 6- and 10-category forced choice Likert Scale. The survey instrument is included as Appendix E.

Survey Results

Figure 1shows the demographics of the workshop participants; 52% White, 38% African-American, 3% Asian, and 5% did not specify race. Female teachers accounted for 83% of workshop participants, while male teachers accounted for 13%. Masters degrees had been earned by 73% of attendees. Figure 2 shows the subject taught by the participants. Half of the participants were Science teachers, 33% taught Math, 11% taught both Math and Science, and 4% taught Technology. Figure 3 shows the attendee's years of teaching experience; 34% have taught for 5 years or less, 24% have taught for 6-10 years, 10% have taught for 11-15 years, 14% have taught for 16-20 years, and 18% have over 25 years of teaching experience.

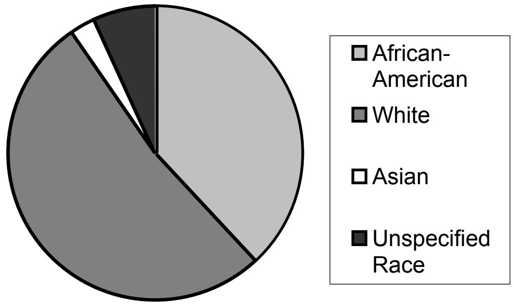


Figure 1: Workshop Participants by Race

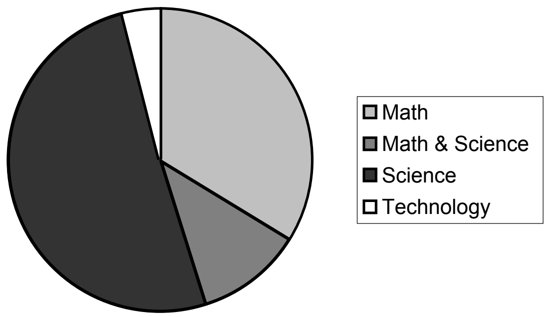


Figure 2: Subject Taught by Workshop Participants

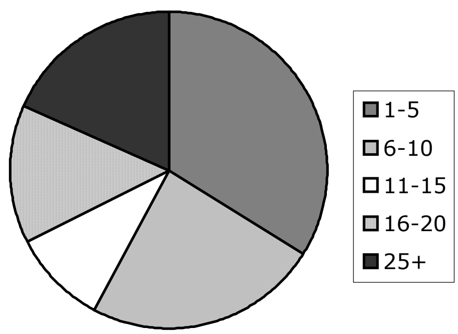


Figure 3: Years of Teaching Experience

Figure 4 illustrates the responses of the participants to general questions regarding the workshop and teaching abilities of the Graduate Teaching Fellows. The responses were uniformly positive. All participants 'Strongly Agree' or 'Agree' with the following statements: 1) I would recommend this workshop to other teachers 2), 2) My knowledge of engineering increased in the workshop, 3) the Graduate Teaching Fellows were good teachers, 4) the Graduate Teaching Fellows were helpful resource experts, and 5) the strategies presented in the lessons will promote inquiry and enhance creative and critical thinking.

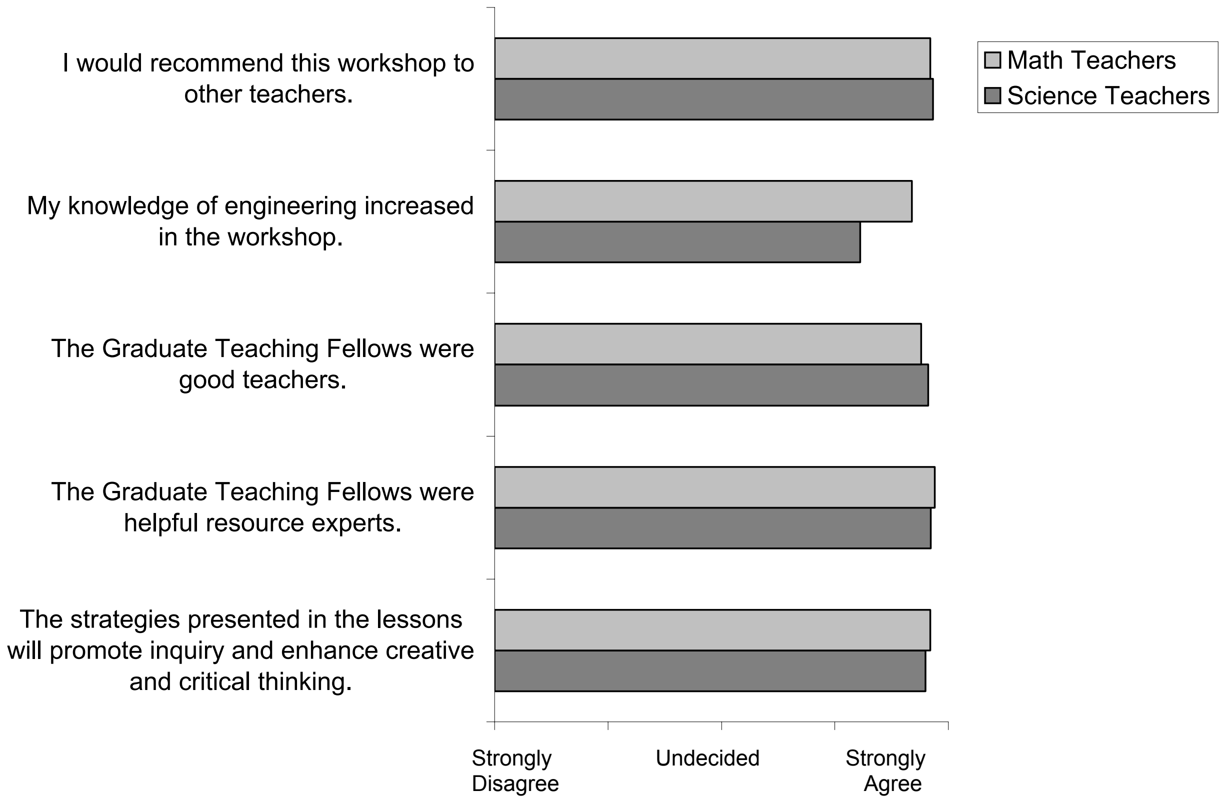


Figure 4: General questions regarding workshop

Figure 5 shows the responses of the participants to questions about the workshops applicability to mathematics. The survey asked participants to indicate how they agree with each statement ranging from Strongly Agree to Strongly Disagree. Math teachers ‘Strongly Agree’ that the activities were problem-based experiences applicable to mathematics, relate to SC Math Standards, enables them to implement new math-related activities, and improved their ability to teach math. Science teachers ‘Agree’ that the activities were problem-based experiences applicable to mathematics and that the workshop enables them to implement new math-related activities. Science teachers were ‘Undecided’ whether the activities relate to SC Math Standards and whether the workshop improved their ability to teach math.

Figure 6 shows the responses of the participants to questions about the workshops applicability to science. The survey asked participants to indicate how they agree with each statement ranging from Strongly Agree to Strongly Disagree. Science teachers ‘Strongly Agree’ that the activities were problem-based experiences applicable to science, relate to SC Science Standards, the workshop enables them to implement new science-related activities, and improved their ability to teach science. Math teachers were ‘Undecided’ whether the activities were problem-based experiences applicable to science. Math teachers ‘Disagree’ whether the activities relate to SC Science Standards, that the workshop enables them to implement new science-related activities and whether the workshop improved their ability to teach science.

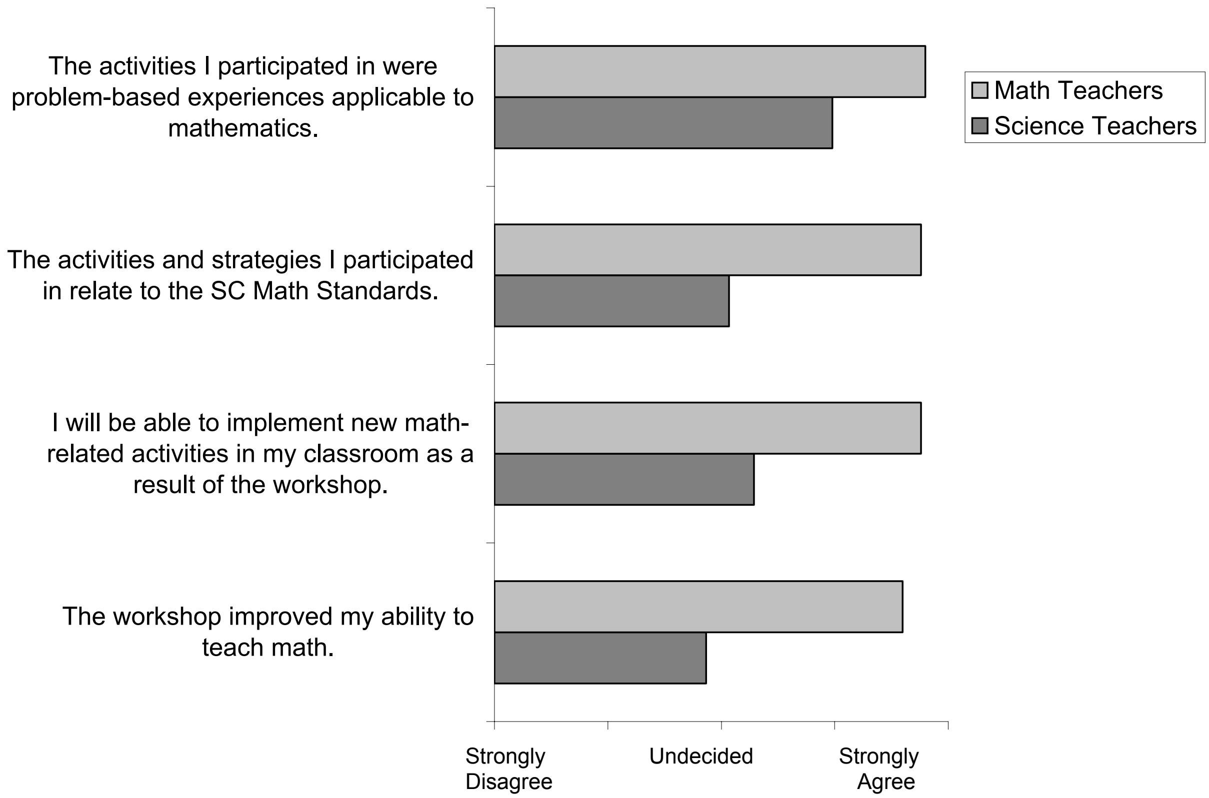


Figure 5: Applicability of Workshop to Math

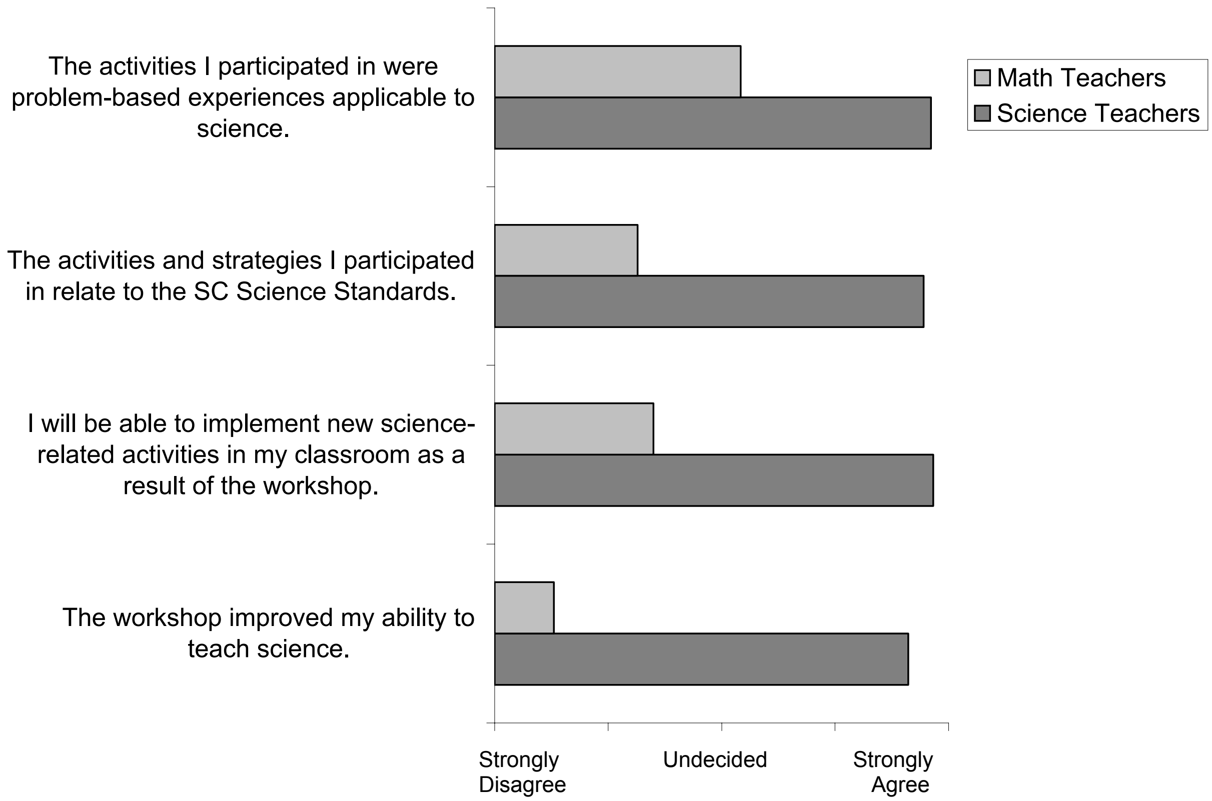


Figure 6: Applicability of Workshop to Science

Figure 7 illustrates the responses of the participants to activity specific questions regarding the degree to which the activities would be appropriate for their classroom setting. Math teachers responded that the 'Forces and Graphing' activity was 'extremely applicable', while the Science teachers responded that the 'variables' aspect was extremely applicable and the slope/intercept aspect was 'very applicable.' Science teachers felt the 'Speakers' activity was 'very applicable' while Math teachers felt it was 'somewhat to very applicable.' Science teachers rated 'Pendulums' extremely applicable, while Math teachers rated it 'very applicable.' Science teachers rated 'Rockets' as 'very' to 'extremely applicable' for all aspects of the activity. Math teachers rated it as 'extremely applicable' for the component dealing with 'calculating flight height', and 'very applicable' for the aspects of 'examining factors influencing flight' and 'optimizing water level.'

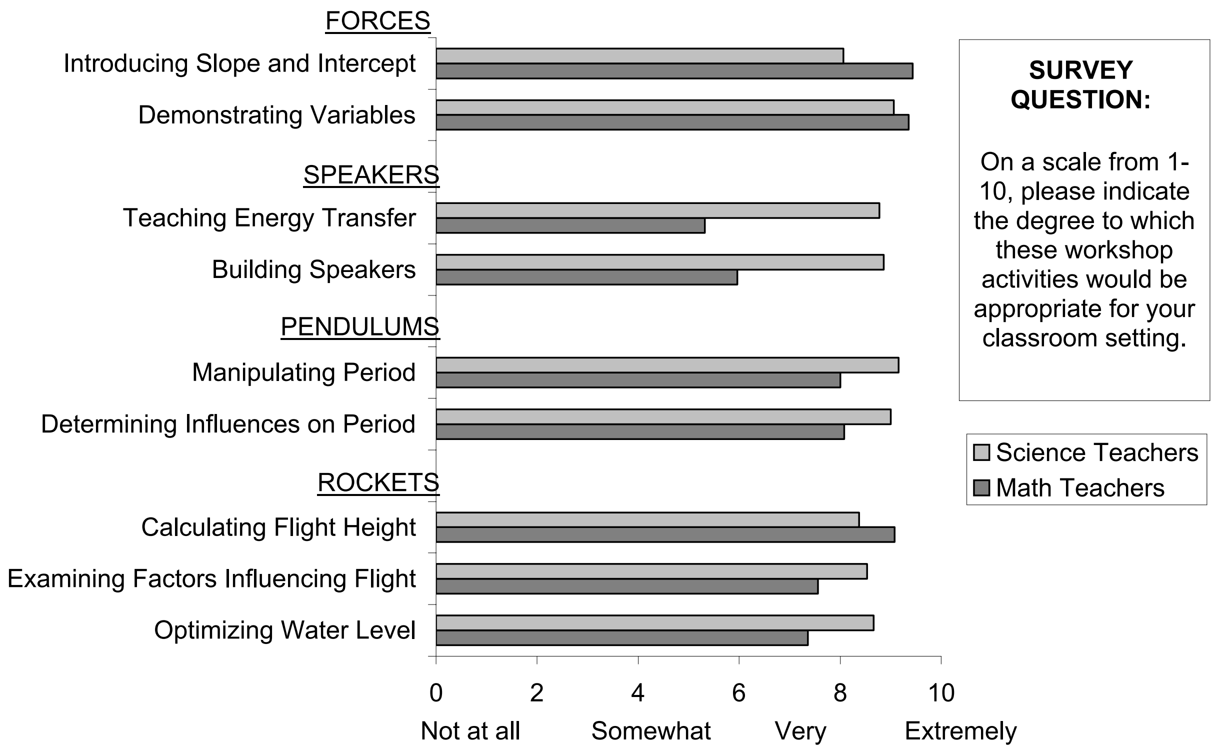


Figure 7: To What Degree are these Workshop Activities Appropriate for Your Classroom Setting as Reported by Participants

Figure 7 shows that both Science and Math teachers agree that the Forces, Pendulum, and Rocket activities are appropriate for their classrooms. These lessons incorporated aspects of both science and math and the teachers saw how the lessons would fit into their classroom. However, Math teachers rate the Speaker activity as a 5/10 in being appropriate for their classroom while Science teachers rate is as a 9/10. This may be because the Speaker activity focused mainly on the topics of energy and magnetism and mentioned math briefly as an extension to the activity by looking at the equation of a coil.

Discussion of Results

As shown previously, participants were asked about the workshops affect on improving their ability to teach math and science. Selected results from science teachers and from math teachers are compared Figure 8. All teachers strongly agreed that the activities promote inquiry and enhance creative and critical thinking, however math teachers strongly agree that the workshop enhances their ability to teach math, while the science teachers responded with ‘agree’ or ‘undecided.’ When asked about the workshops affect on improving their ability to teach science, science teachers ‘strongly agree’ and math teachers ‘disagree’ or were ‘undecided.’ All teachers ‘strongly agree’ that the strategies presented in the lessons will promote inquiry and enhance creative and critical thinking. The authors feel that this is an interesting finding because teachers performed the same activities at the same time, often in groups that contained both math and science teachers, yet they perceived the workshop differently.

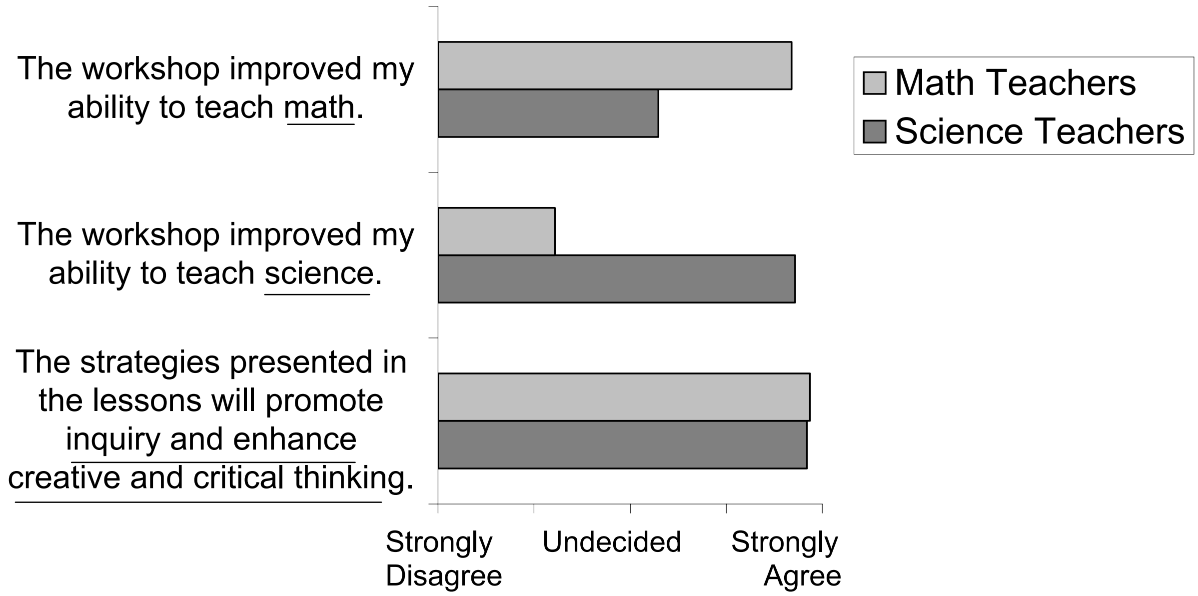


Figure 8: Applicability of workshop to subject areas as reported by Institute Participants

There is a body of research related to how subject areas in K-12 schools divide and define teachers into subject subcultures.[7, 8] This can influence the manner in which they take in new content in the context of the subject area with which they are associated. The teacher may construct an identity based on the subject he or she teaches. This becomes like a lens through which they view new experiences without seeing the connections to other subject areas. This may be evident in our survey data because all participants were middle school teachers who teach specific subjects rather than elementary school teachers who teach all or most subjects to one classroom of students.

One way to attempt to correct this notion is to state all standards relating to the activity on the lesson plan in both the Science and Math content areas and also discuss them during the Institute. Another approach would be to discuss how these projects could involve both a math and science class working together. An example of this could be the Rocket activity: a science class could investigate effect of the water level and fins on the rockets, while a math class could focus on the altimeter construction, measurements, and height calculations.

Concluding Remarks

The outcomes of the GK-12 Institute for Teachers indicate that the primary goal of enhancing teacher's abilities to use engineering related educational materials to teach science and mathematics is being met. Future Institutes may emphasize the multidisciplinary aspect of engineering related activities in order to show connections between math and science.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant Number 0440568. All opinions expressed within are the authors' and do not necessarily reflect those of the National Science Foundation.

Bibliography

1. National Science Foundation, NSF Graduate Teaching Fellows In K-12 Education (GK-12) http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5472&from=fund

2. A. Caicedo, J. Lyons, S. Thompson, (2006) "Investigating Outcomes for GK-12 Teacher Partners and GK-12 Summer Institute Participants," Proceedings of the 2006 American Society for Engineering Education Annual Conference, Chicago, Illinois

3. J. DeGrazia, J. Sullivan, L. Carlson, and D. Carlson, (2001). "A K-12/University Partnership: Creating Tomorrow's Engineers," Journal of Engineering Education, October 2001, pp. 557 – 563.

4. J. Hamann, L. Hutchinson, A. Moore, (2006) "Thinking and Doing Math and Science with Engineering: A Partnership," Proceedings of the 2006 American Society for Engineering Education Annual Conference, Chicago, Illinois

5. S. Kearns, C. Rogers, J. Barsosky, M. Portsmore, C. Rogers, (2001) "Successful methods for introducing engineering into the first grade classroom" Proceedings of the 2001 American Society for Engineering Education Annual Conference, Albuquerque, New Mexico

6. M. Lee, J. Rinehart, S. Starks, K. Villatoro, (2006) "Discover Engineering – A High School Conference for Students and Teachers," Proceedings of the 2006 American Society for Engineering Education Annual Conference, Chicago, Illinois

7. P Grossman, S. Stodolsky, (1995). "Content as Context: The Role of School Subjects in Secondary School Teaching," Educational Researcher, Vol. 24, No. 8 (Nov., 1995), pp. 5-11+23

8. J. Spillane, (2000) "A Fifth-Grade Teacher's Reconstruction of Mathematics and Literacy Teaching: Exploring Interactions among Identity, Learning, and Subject Matter." The Elementary School Journal, Vol. 100, No. 4, Special Issue: Mathematics (Mar., 2000), pp. 307-330

9. "Forces and Graphing" Activity, TeachEngineering.com http://www.teachengineering.com/view_activity.php?url=http://www.teachengineering.com/collection/usc_/activities/usc_forcegraphing/usc_forcesgraphing.xml Accessed March 2007

10. "Yogurt Cup Speakers" Activity, TeachEngineering.com, http://www.teachengineering.com/view_activity.php?url=http://www.teachengineering.com/collection/usc_/activities/usc_speakers/usc_speakers_activity1.xml Accessed March 2007

APPENDIX A: Lesson Plan for 'Forces and Math'

Forces and Graphing

Lesson Plan by Veronica Addison

Overview: This lesson introduces students to forces, data collection/analysis and relationships between variables.

Suggested grade level(s): Beginning Algebra
Concepts covered: relationships, equation of a line, slope
Standards: 6-8 & 9-12 Algebra:
I. A, B&C Understand patterns, relations, and functions;
II. Represent and analyze mathematical situations and structures using algebraic symbols;
III. Use mathematical models to represent and understand quantitative relationships.
IV. Analyze change in various contexts.

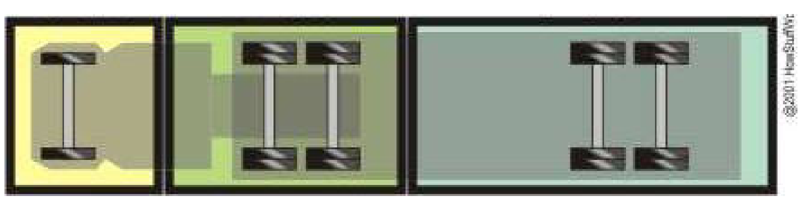
Length of lesson: 45 minutes

Materials required:
1 2x4 board, 4 feet long
2 bathroom scales (analog)
2 wooden blocks (about 6 inches long)

Lesson Format

Phase I. Engage

How could you weigh Fat Albert? Or a Semi Truck for that matter? Several scales can be used to weigh a heavy object. For example, one-stop axle weighing uses several scales that work together to determine the axle weight plus the gross weight. In this activity we will explore loads and reaction forces.

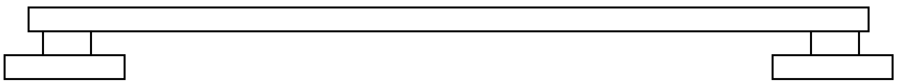


Steering Axle Drive Axle Scale Trailer Axle Scale
www.howstuffworks.com

Phase II. Explore

Step 1: Place 1 block on each scale

Step 2: Place the beam onto the scales as shown below in the photo and sketch

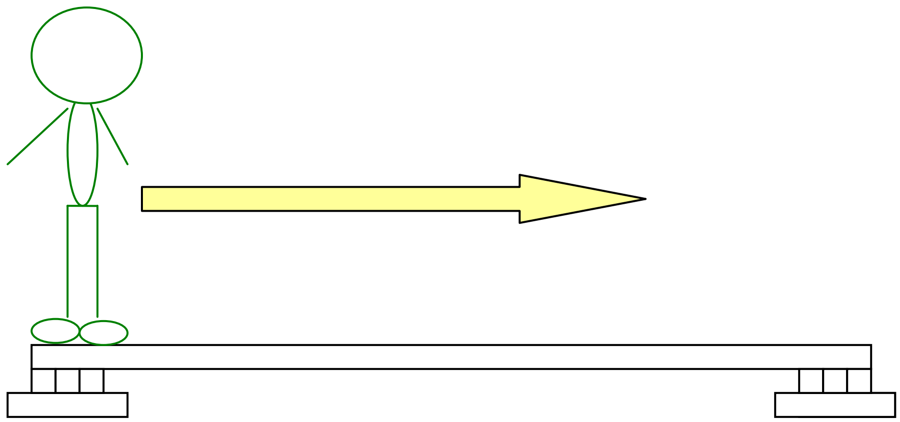


Step 3: Zero the scales

Step 4: Have the students create a data table, an example table is shown below

position	reaction force 1	reaction force 2
a (ft)	R1 (lbs)	R2 (lbs)
0		
0.5		
1		
1.5		
2		
2.5		
3		
3.5		
4		

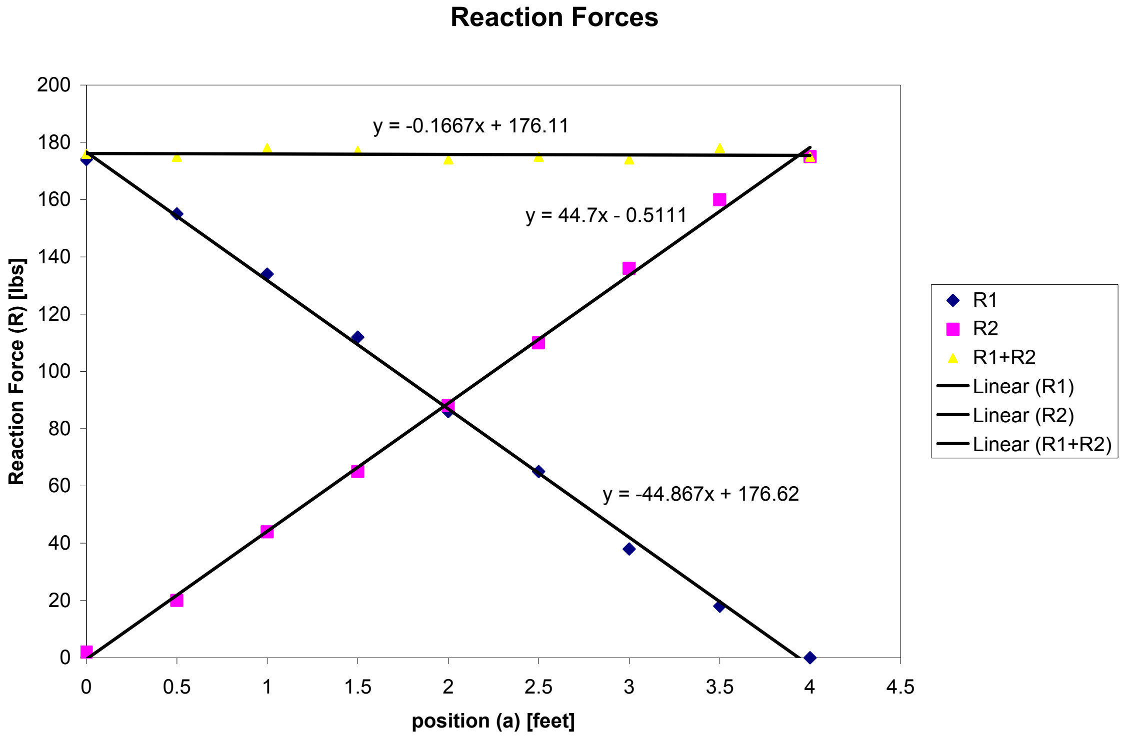
Step 6: Have the person acting as the load stand at each location (a) shown in the table moving from 0 feet to 4 feet in 6 inch increments. Record the reaction forces R1, R2 at each location.



Do you notice any patterns in your data?

Step 7: Create a graph of your data showing load position (a) vs. reaction forces (R1 & R2). What does the graph tell you? You may have noticed a relationship between R1, R2 & P. How could you show that on the graph?
This step can be done by hand using graph paper or on the computer using Excel. It would be beneficial for the students to approximate a trend line and approximate the equation for each line they graph.

distance	reaction force	reaction force	
a	**R1**	**R2**	**R1+R2**
(feet)	**(pounds)**	**(pounds)**	**(pounds)**
0	174	2	176
0.5	155	20	175
1	134	44	178
1.5	112	65	177
2	86	88	174
2.5	65	110	175
3	38	136	174
3.5	18	160	178
4	0	175	175



Phase III. Explain

The graph shows two lines each representing a reaction force. The lines intersect at around a=4, which is the midpoint of your beam. This tells us that the reaction forces are equal to each other when the load is placed in the middle of the beam. The R1 line begins at the value P and ends at 0. R2 begins at 0 and ends at P. The lines also have opposite slopes, which tell us that the rate of change is the same for both- but one is increasing and one is decreasing.

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Phase IV. Elaborate

Suppose you had a person who applied a heavier load, what do you think their data would look like?

Phase V. Evaluate

A sample rubric is shown below.

CATEGORY	4	3	2	1
Data	Professional looking and accurate representation of the data in tables. Tables and are labeled and titled.	Accurate representation of the data in tables. Tables are labeled and titled.	Tables are not accurate representation of the data.	No tables are presented.
Graphs	Professional looking and accurate representation of the data in graphs. Graphs and are labeled and titled.	Accurate representation of the data in graphs. Graphs are labeled and titled.	Graphs are not accurate representation of the data.	No graphs are presented.
Variables	All variables are clearly described with all relevant details.	All variables are clearly described with most relevant details.	Most variables are clearly described with most relevant details.	Variables are not described OR the majority lack sufficient detail.
Analysis	The relationship between the variables is discussed and trends/patterns logically analyzed. Predictions are made about what might happen if part of the lab were changed or how the experimental design could be changed.	The relationship between the variables is discussed and trends/patterns logically analyzed.	The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data.	The relationship between the variables is not discussed.

APPENDIX B: Lesson Plan for 'Pendulum Challenge'

Pendulum Challenge

Lesson Plan by Veronica Addison and Trevor Roebuck
Based on ZOOM

Overview: This lesson uses pendulums to show energy transfer, teach experiment design and illustrate relationships between variables.

Suggested grade level(s):	6th science, Algebra I
Concepts covered:	Process Skills, Variables, Forms and Transfer of Energy
Standards:	6th Science: IV C 1&2 Energy Transfer, 6-8 & 9-12 Algebra: IA,B&C Understand patterns, relations, and functions
Length of lesson:	45 minutes

Materials required:

For the demonstration:	rubber band, string, small bouncy ball or tennis ball, tape
For each group of 4:	stopwatch, ruler or measuring tape, string, masking tape, foil, graph paper, and one of the following: small cup with about 20 marbles, or 10 magnets

Lesson Format

Phase I. Engage

Being the lesson with the "Pendulum of Fear!"

1. Tie the string around the rubber band.
2. Wind the rubber band around the ball twice so that the string stays on the ball.
3. Tape the end of the string to the top of a doorway. See how it swings back and forth.
4. To make it a Pendulum of Fear, stand in one spot a couple of feet away from the ball. It's VERY important that you don't move. Put the ball up to your nose and let it go.
5. It looks like the ball is going to hit you in the nose, but it doesn't. It comes just short of your nose. That's because while the pendulum swings back and forth, it has to use some of its energy to push the air out of the way. Since it doesn't have as much energy, it can't swing back high enough to reach your nose.

It is converting potential energy, from its height, into kinetic energy, the energy of motion. Once it passes the lowest point, the opposite begins to happen. It is now moving against gravity, and some of its kinetic energy is converted into potential energy. Once all of the kinetic energy has been converted, it stops and starts to move downwards again.

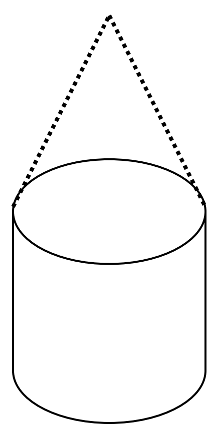
A nice illustration of this concept is to have 2 cups or beakers. One should be full and the other empty. When the pendulum is pulled back, ready to be released, the empty cup represents its kinetic energy and the full cup represents the potential energy. Once the pendulum is released and begins to swing down it loses some potential energy and gains kinetic energy. Show this by pouring some of the water out of the “potential” cup into the “kinetic” cup. When the pendulum is at its lowest point, all the water should be in the “kinetic” cup. As the pendulum continues swinging, its kinetic energy is converted into potential energy. Pour the water back into the “potential” cup.

In a perfect system, this would keep happening over and over, with no energy lost. In reality, there is resistance from the air, friction with the string, all sorts of things to drain away some of the energy. This means that each swing will not go quite as high as the one before it. You can show this by spilling some of the water when pouring from one cup to the other.

Phase II. Explore

Step 1: Each group should be given the following materials: stopwatch, ruler or measuring tape, pipe cleaner, string, masking tape, foil, graph paper, and one of the following: small cup with about 20 marbles, or 10 magnets.

Step 2: If you are using small cups with marbles, poke a hole in each side of the cup using a paper clip. Use a pipe cleaner to tie a handle on the cup, as shown below. Now tie a longer piece of string to the handle. If you are using magnets, tie one to a long piece of string.



Step 3: Tie or tape the long piece of string to something like a desk or doorframe. If this is not available you can tape it to something similar. Just make sure you have enough room to swing the pendulum back and forth.

Step 4: Fill the cup with some marbles to give it some weight and cover the opening with foil or masking tape. If you are using magnets, attach a few magnets. You are now ready for experimentation.

Step 5: Here comes the challenge! Now see if you can get the pendulum to swing back and forth in 1 second. What will you need to change? The weight? The length of the string? Have the students discuss in their groups what data should be recorded. An example table is shown. Students will most likely need more than 10 trials; this is just shown as an example. For each trial the data recorder should record the length of the string, number of marbles or magnets, and the time it takes for the pendulum to swing back and forth.

Trial #	Length of String (cm)	Number of Marbles	Period (seconds)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Step 6: What can you conclude from the results? Find a good way to represent your data that illustrates your findings.

Phase III. Explain

Repetitive motion is called periodic motion. The time it takes for the pendulum to swing back and forth is called the period of the pendulum. The data should show that as the length of the string increases, the period also increases.
For small amplitudes, the period, *T*, of the pendulum can be approximated by the formula:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

where: L is the pendulum length
g is the acceleration due to gravity

Phase IV. Elaborate

Challenge the students to make their pendulum have a period of 5 seconds or 2 seconds, this will depend on the space you have available. You might take the class outside and tie a bucket filled with sand to something tall like a tree or the monkeybars at a playground. With the longer string length outside you could have a large period. Or they could calculate what the pendulum length needs to be in order to achieve a given period.

Phase V. Evaluate

A sample rubric is shown below.

CATEGORY	4	3	2	1
Data	Professional looking and accurate representation of the data in tables. Tables and are labeled and titled.	Accurate representation of the data in tables. Tables are labeled and titled.	Tables are not accurate representation of the data.	No tables are presented.
Graphs	Professional looking and accurate representation of the data in graphs. Graphs and are labeled and titled.	Accurate representation of the data in graphs. Graphs are labeled and titled.	Graphs are not accurate representation of the data.	No graphs are presented.
Variables	All variables are clearly described with all relevant details.	All variables are clearly described with most relevant details.	Most variables are clearly described with most relevant details.	Variables are not described OR the majority lack sufficient detail.
Analysis	The relationship between the variables is discussed and trends/patterns logically analyzed. Predictions are made about what might happen if part of the lab were changed or how the experimental design could be changed.	The relationship between the variables is discussed and trends/patterns logically analyzed.	The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data.	The relationship between the variables is not discussed.

Notes

• An interactive online pendulum simulation can be found at
http://pbskids.org/zoom/games/pendulum/swing.html

http://www.myphysicslab.com/pendulum1.html

How Stuff Works: Pendulum Clocks http://home.howstuffworks.com/clock.htm

Pendulum Calculator: http://hyperphysics.phy-astr.gsu.edu/hbase/pend.html#c2

APPENDIX C: Lesson Plan for Bottle Rockets

Bottle Rockets

Lesson Plan by Trevor Roebuck

Overview: This lesson illustrates the relationship between Force and mass.

Suggested grade level(s): Grades 6^{th} – 9^{th}
Concepts covered:
Energy transfer:
Potential and kinetic energy
Applied force vs. Mass

6^{th} Grade Standards:
Science
IA 1-8

Length of lesson: 2-3 hrs

Materials required per class:
9 -empty 2 Liter bottles + 1 additional bottle per group
1 -bottle rocket launcher
3 or more stop watches
graphing paper
water
poster board
tape and scissors

Lesson Format

Phase I. Engage

Begin a discussing on the relationship between Force, Mass and how they relate.
Instigate a friendly rocket competition between groups and ask them if they would enjoy watching the teacher get soaked.

Phase II. Explore

Step 1: Begin by having volunteers fill each of the empty 2 liter bottles with water. Each of the 9 bottles must be filled to a different volume ranging from 0 liters to full (2 liters) in increments of 250 milliliters.

While those bottles are being filled have the rest of the class write the following chart or design their own.

liters of water	height in time (seconds) or in distance (feet)	Rank	Predicted Rank
2			
1.75			
1.5			
1.25			
1			
0.75			
0.5			
0.25			
0			

Step 2: When each of the bottles are filled to a specific volume have them mark the bottles with permanent markers and label the volume on them.

Step 3: Set those 9 specifically filled bottles aside and give each group an empty bottle, a piece of poster board and some tape. Allow the groups to design tail fins for their group rocket.

Step 4: Take the bottles and the class outside to an open field away from buildings and groups of people. The baseball/softball field works, because it has the catching fence for the students to stand behind. Be sure to bring the stop watches or height measuring devices or both and the launching pad.

Step 5: Nail the launch pad down to the ground through the predrilled holes, while doing this have students make an inference about what bottles they think will go the highest and predict their rankings.

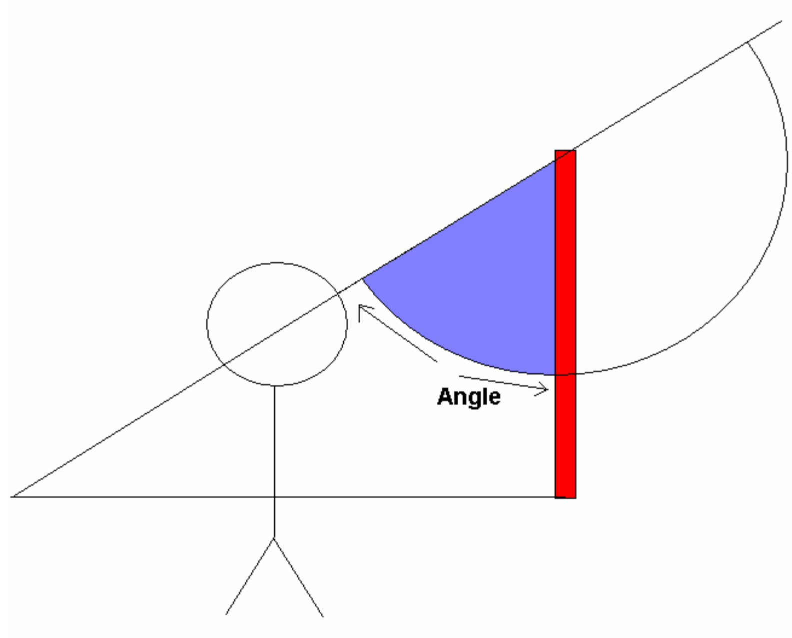
Step 6: Beginning with the fullest 2 Liter bottle of water, without fins, remove the top and place the bottle on the launching pad. Make sure that the bottle is all of the way down so that the locking pin can completely grab the rim of the bottle, then slide in the launching pin. Pull on the bottle to make sure the bottle is completely locked to the launching pad.

Step 7: Select a fixed pressure to be used for this grouping of tests no higher than 60 psi and have the students prepare to time or measure the flight height.

Step 8: Take the information from rocket flight and fill it into the chart. Use this information to select the best ratio of water to air.
* The flight information will be time from take off to maximum height and possibly the angle of the maximum height *

To get the angle of the flight:

1. Attach a ruler to a protractor by placing a brass plated fastener through the hole in the end of the ruler, then into the protractor.
2. Fold the tabs of the brass plated fastener.
3. look down the protractor's straight edge
4. Observe what angle the ruler crosses the protractor (represented by blue)



Step 9: Now fill the finned rockets to the optimal volume of water and launch (keep track of height or time or both).

Step 10: Record all of this information and see which flew the highest.

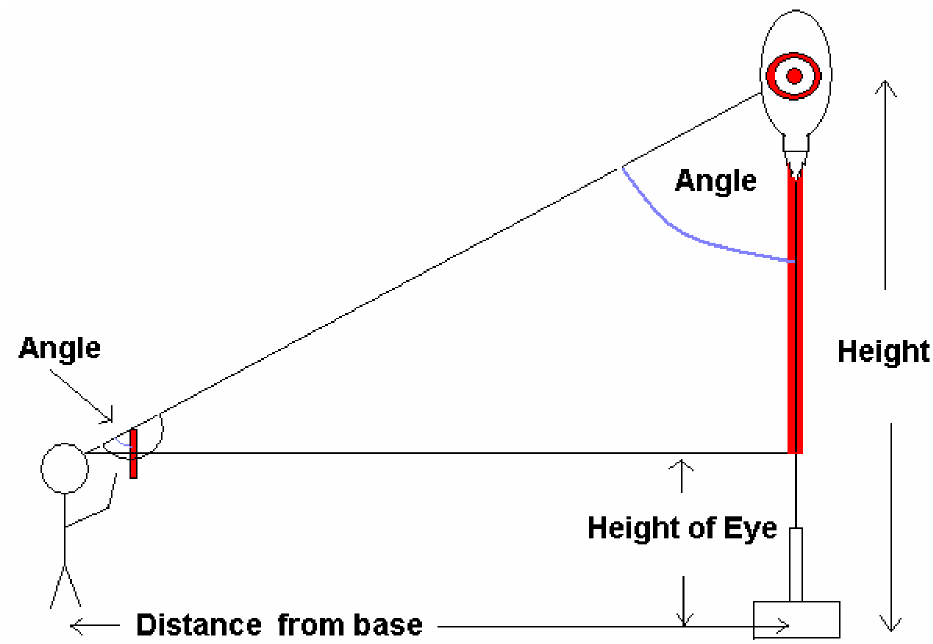
Converting the angle to distance by relating triangles:

1. Using graphing paper and a protractor recreate the triangle in figure 1.
2. Count the boxes for the height of the triangle and fill into equation 1.
3. Count the boxes for the base of the triangle and fill into equation 1.
4. Take the distance from the launching pad to where you made your angle measurements and fill that into equation 1.

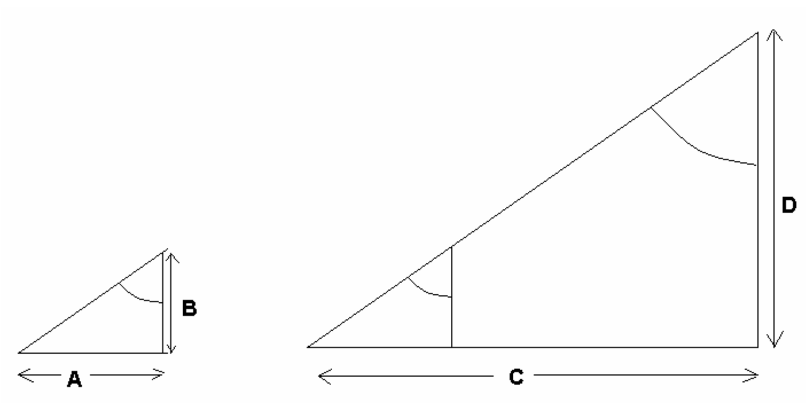
Equation 1

$$\frac{Height(boxes)}{Base(boxes)} = \frac{RocketHeight(feet)}{Launchingpad(feet)}$$

This equation will give you the maximum height of the rocket since the triangles are similar.



Another example of similar triangles:



Equation 2

$$\frac{B}{A} = \frac{D}{C}$$

*Equations 1 and 2 represent the same concept *

• **Science process skills used in this stage:** Inquiry, Observe, Communicate, Infer and Predict

Phase III. Explain

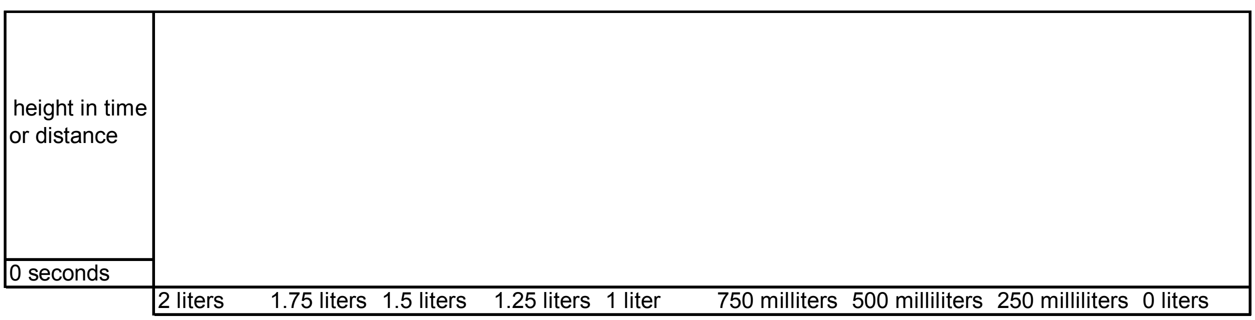
The bottle rockets can be compared to a kid sitting on a skate board with a bowling ball. If the student throws the ball while sitting on the skateboard this should cause the skateboard and the kid to roll in the opposite direction. In the case of the bottle rocket the water is the bowling ball. The only way that the water can be displaced is by the pressure inside the bottle being greater than the pressure outside of the bottle.

Filling the 2 liter bottle up completely water should give the worst results for height. Since the bottle is completely filled with water there is no room for air. Since water is a liquid it will not compress and there is not much water displaced because the volume of the water wants to remain constant. Allowing a compressible gas such as air inside of the bottle allows you to increase the pressure which increases the density of the gas. This gas (air) wants to return to atmospheric pressure, which means it is going to have to expand to return to its normal volume. When the bottle is released from the launching pad the pressure in the air forces the water out of the bottle. Using Newton's 2nd law (Force = mass X acceleration) the accelerating mass of water causes a force on the bottle in the opposite direction causing the bottle to move into space.

Depending on the pressure there is a point at which too little air will not expand enough and force all of the water out of the bottle and too much air will expand a lot, but not have any water or "bowling balls" to throw out backwards.

Phase IV. Elaborate

Have the students plot the numbers in Excel and see if they see which volume of water reaches the greatest height.



Can the students take smaller increments of water measurements in this area to suggest the best ratio of water to air to reach the highest possible for this pressure.

Have the students measure both the height time and the back to earth time. Do they notice anything different?

Have the students repeat the tests at lower pressures and repeat their graphs. Do they notice an unequal shift in the data?

Phase V. Evaluate

A sample rubric is shown below:

CATEGORY	4	3	2	1
Data	Professional looking and accurate representation of the data in tables. Tables and are labeled and titled.	Accurate representation of the data in tables. Tables are labeled and titled.	Tables are not accurate representation of the data.	No tables are presented.
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Notes

- Related resources

  http://www.rokit.com/
  http://science.howstuffworks.com/rocket.htm
  http://www.antigravityresearch.com/
  http://users.hubwest.com/gordo/CO2Launcher.html#Launch%20Tube
  http://www.water-rockets.com/javasim/index.html
  http://www.seeds2lrn.com/rocketSoftware.html

APPENDIX D: Lesson Plan for 'Yogurt Cup Speakers"

Yogurt Speakers

Lesson Plan by Trevor Roebuck

Overview:
This lesson illustrates the role of electricity and magnetism in a real life application of a speaker.

Suggested grade level(s): Grades 6^{th} – 9^{th}
Concepts covered:
Physical Properties and Changes of Matter
Current, Circuits (parallel or series), Resistance, Voltage/Current

Magnetism: Repulsion or attraction and Polarity

Energy transfer: chemical potential, electrical to heat and work (mechanical and sound waves).

6^{th} Grade Science Standards:

Physical Properties and Changes of Matter

A. Properties and Changes of Properties in Matter IIC.

C. Energy is Transferred in Many Ways
IA, IB, IIA, IIB, IIIE, IIIF, IVA, IVB, IVC, IVD

Length of lesson: 1 hr

Materials required per group:

Item Quantity	Description	Price / Quantity	Home Depot Part number
1- round magnet	3/4 inch diameter	$2.29 for 8	609-145
or			
1- round magnet	1/2 inch diameter	$1.98 for 10	609-137
or			Walmart
1- round magnet	3/4 inch diameter	$5.99 for 50	
			Radio Shack
15 ft Coil wire	Enamel coated coil wire	$4.89 for 315 ft	278-1345
1 plastic container	Yogurt, whip topping, butter	Kids bring from home	

Lesson Format

Phase I. Engage

-Briefly review magnets and their polarities. Question the students about where magnets may exist and if they have seen any in use. Possibly bring out a speaker or the home made speaker and have it playing some music.

- What if you could control the polarity of a magnet. Introduce the idea of an electro magnet.

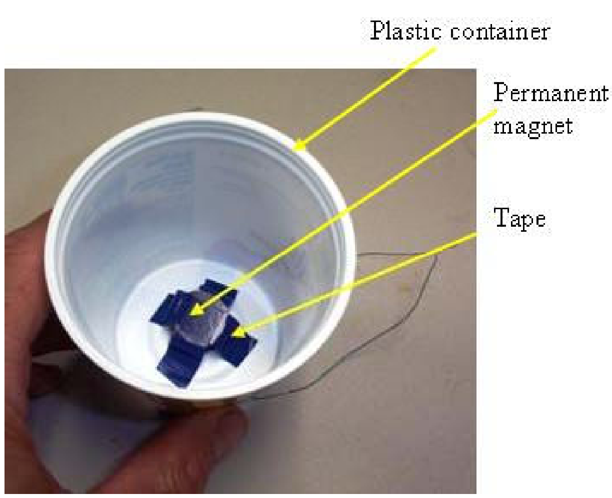
Phase II. Explore

Step 1: Before the students enter the classroom set out pairs of magnets at each table. When the students enter have them explore, if they have not already started on their own, the affects the magnets have on each other when similar poles are near each other i.e. either North to North or South to South. Notice the affects the magnets have on each other when dissimilar poles are near each other i.e. North to South or South to North.

Step 2: Have the students create an electro magnet by winding roughly 6 to 15 feet of the wire around a cylindrical object such as a c or d cell battery (leave 2 inches of wire hanging off of each end).

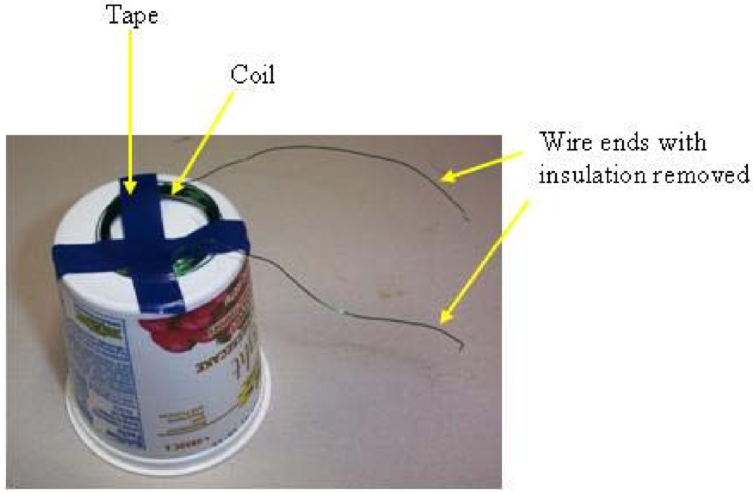
Step 3: While keeping the wire in the shape of a coil, delicately remove the wire from the cylindrical object and have them temporarily hook a battery to the electro magnet while near the magnets. What happens? Hook the battery up differently and see what happens to the magnets.

Step 4: Attach the coil and the magnet to the container with either tape or hot glue. Attach the coil and magnet in such a way that the coil and magnet are next to each other (There are many different creative ways to do this and all should work).



The attached magnet

Step 5: Run the wires off of the coil, play around with the circuit and hook up the battery in a couple of different ways. Hook the speaker up to a radio with detachable speakers and listen.



The attached coil

Yogurt Speaker in action

• **Science process skills used in this stage:** Inquiry, Observe, Communicate, Infer and Predict

Phase III. Explain

Similar poles on magnets repel, while dissimilar poles attract. Running current through a wire creates a magnetic field similar to a field of a magnet. That field's direction and magnitude depend on the magnitude of the current (I) and the direction of the current (I). The direction of the magnetic field can be determined by using the right hand rule:

- Place the wire in your hand with your thumb in the direction of the current (point your thumb from positive (+) to negative(-))

- Close your hand so that your fingers wrap around the wire. Your fingers are pointing in the direction of the magnetic field lines.

By wrapping the wire into loops you increase the amount of magnetic field, because you are stacking the field lines, which increase the strength of the magnetic field. The strength of the field now depends on the number of loops and the amount of current (I). By using an electro magnet the polarity can be changed (i.e. North and South polarity can be controlled) with the change in direction of current.

Phase IV. Elaborate

Have the students change the amount of current and monitor the changes in the speaker's movement.

Have the students change the direction of the current and monitor the change in the speaker's movement.

Can they relate the current's change in direction or change in amplitude to the change in movement in the speaker.

Do the results match the equation of a coil?

$$B = \mu_o \cdot n \cdot I$$

Where B is the magnetic field
μ some constant known as the permeability of free space
N is the number of coils
I is the current magnitude

The best thing about this magnet is that you can control the power and the polarity of the magnet. By connecting and disconnecting a power supply to the coil the magnetic field lines can be turned on and off, if this is done near a magnet and a vibration or movement can be sensed. You have just taken electrical energy from chemical energy and transformed it into heat and mechanical energy.

Phase V. Evaluate

Possible Quiz Questions:

1. How many different forms of energy exist in this circuit?
2. Is this circuit in series or parallel?
3. What poles attracted or repelled?
4. Was their a conductor, insulator or both used?
5. How could you increase the strength of the speaker/electro-magnet?

OR

CATEGORY	4	3	2	1
Participation	Attraction and repelling forces of magnets were discovered. Coils were made and the windings were counted.	Attraction and repelling forces of magnets were discovered. Coils were made, but the windings were not counted.	Attraction and repelling forces of magnets were not discovered or the coils were not made.	Coils were not made and nothing was observed in reference to magnets.
Variables	All variables are clearly described with all relevant details.	All variables are clearly described with most relevant details.	Most variables are clearly described with most relevant details.	Variables are not described OR the majority lack sufficient detail.
Analysis	The relationship between the variables is discussed and trends/patterns logically analyzed. Predictions are made about what might happen if part of the lab were changed or how the experimental design could be changed.	The relationship between the variables is discussed and trends/patterns logically analyzed.	The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data.	The relationship between the variables is not discussed.

Notes

- Ways to change the lesson to suit other age levels.

  Knowing that there are 3 variables that influence these electromagnetic coils/speakers (current, number of coils and direction of current (I)) have the students devise an experiment on their own to test each of the variables influences.
- Related resources

  http://electronics.howstuffworks.com/speaker.htm

APPENDIX E: Participant Survey

Participant Survey
GK-12 INSTITUTE FOR TEACHERS: 30 JUNE 2005

1. Please provide information about your demographics by checking the appropriate boxes.

Gender	Race	Ethnicity	Highest Degree Earned	Years Teaching Experience	Grade(s) Teaching Next Year	Subject(s) Teaching Next Year
☐ Male ☐ Female	☐ American Indian ☐ Asian ☐ African American ☐ Pacific Islander ☐ White ☐ Other	☐ Hispanic or Latino ☐ Not Hispanic or Latino	☐ Associates ☐ Bachelors ☐ Masters ☐ Master+30 ☐ Doctorate ☐ Other	☐ 1-2 ☐ 3-5 ☐ 6-9 ☐ 10-15 ☐ 16-22 ☐ 23+	☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ Other ________	☐ Algebra ☐ Geometry ☐ Physical Science ☐ General Science ☐ Other __________

2. Please indicate how you agree or disagree with each statement by circling the appropriate letters.

SA Strongly Agree **A** Agree **U** Undecided **D** Disagree **SD** Strongly Disagree **NA** Not Applicable

a.	The workshop improved my ability to teach science.	SA	A	U	D	SD	NA
b.	The workshop improved my ability to teach math.	SA	A	U	D	SD	NA
c.	I will be able to implement new science-related activities in my classroom as a result of the workshop.	SA	A	U	D	SD	NA
d.	I will be able to implement new math-related activities in my classroom as a result of the workshop.	SA	A	U	D	SD	NA
e.	The activities and strategies I participated in relate to the SC Science Standards.	SA	A	U	D	SD	NA
f.	The activities and strategies I participated in relate to the SC Math Standards.	SA	A	U	D	SD	NA
g.	The activities I participated in were problem-based experiences applicable to science.	SA	A	U	D	SD	NA
h.	The activities I participated in were problem-based experiences applicable to mathematics.	SA	A	U	D	SD	NA
i.	The strategies presented in the lessons will promote inquiry and enhance creative and critical thinking.	SA	A	U	D	SD	NA
j.	The Graduate Teaching Fellows were helpful resource experts.	SA	A	U	D	SD	NA
k.	The Graduate Teaching Fellows were good teachers.	SA	A	U	D	SD	NA
l.	My knowledge of engineering increased in the workshop.	SA	A	U	D	SD	NA
m.	I would recommend this workshop to other teachers.	SA	A	U	D	SD	NA

3. On a scale from 1-10, please indicate the degree to which these workshop activities would be appropriate for your classroom setting.

Rockets

a) Determining Optimal Water Level

0 1 2 3 4 5 6 7 8 9 10

Not at all Somewhat Very Extremely

b) Examining Factors that Influence Flight

0 1 2 3 4 5 6 7 8 9 10

Not at all Somewhat Very Extremely

c) Calculating Flight Height

0 1 2 3 4 5 6 7 8 9 10

Not at all Somewhat Very Extremely

Pendulums

d) Determining Influences on the Period of a Pendulum

0 1 2 3 4 5 6 7 8 9 10

Not at all Somewhat Very Extremely

e) Manipulating the Period of the Pendulum

0 1 2 3 4 5 6 7 8 9 10

Not at all Somewhat Very Extremely

Speakers

f) Speaker Building

0 1 2 3 4 5 6 7 8 9 10

Not at all Somewhat Very Extremely

g) Using Speakers to Teach Concepts Related to Energy Transfer

0 1 2 3 4 5 6 7 8 9 10

Not at all Somewhat Very Extremely

Forces and Graphing

h) Demonstrating Relationships between Variables

0 1 2 3 4 5 6 7 8 9 10

Not at all Somewhat Very Extremely

i) Introducing the Concepts of the Slope and Intercept of a Line

0 1 2 3 4 5 6 7 8 9 10

Not at all Somewhat Very Extremely

4. What was the best part of this workshop?

5. What was the worst part of this workshop?

6. Please provide suggestions for improving the workshop and/or give us any other comments.