Incorporating Engineering into High School Algebra and Trigonometry: An Initiative of the Georgia Tech Student and Teacher Enhancement Partnership (STEP) Program

William H. Robinson[a], Adam O. Austin[a], Demetris L. Geddis[a],
Donna C. Llewellyn[b], and Marion C. Usselman[c]

[a]School of Electrical and Computer Engineering/
[b]Center for the Enhancement of Teaching and Learning (CETL)/
[c]Center for Education Integrating Science, Mathematics, and Computing (CEISMC)
Georgia Institute of Technology

Abstract

There is a growing awareness among educators that engineering can enhance the K-12 curriculum by providing "real world" scenarios that help develop problem-solving skills in students. This paper presents activities designed to incorporate engineering concepts into high school mathematics education. Three graduate students of Georgia Tech's Student and Teacher Enhancement Partnership (STEP) program directly assisted high school mathematics teachers to develop hands-on approaches for algebra and trigonometry classes. These laboratory activities were incorporated into the normal lesson plan. Both the high school students and teachers benefited from using laboratory activities to demonstrate specific principles such as linearity and trigonometric functions.

1. Introduction

As our society becomes increasingly technology oriented, we depend ever more upon a solid educational foundation in science, technology, engineering, and mathematics (STEM). Dr. Robert Moses, Director of the Algebra Project, argues that proficiency in mathematics is required as a functional member of society: "In the Age of Computers, Algebra is a passport for passage into virtually every avenue of the job market and every street of schooling."[1] Trigonometric functions are also used throughout science and engineering. Unfortunately, research presented by Hsiu-Zu Ho describes a "math anxiety" that negatively affects the performance of students[2] and effectively bars them from entering careers that require a firm knowledge of mathematics. To counter this anxiety and improve student achievement, Alan Greenspan encourages "a deeper interaction with numbers and their manipulation to a point at which students are confident and proud of their level of skills."[3]

To emphasize the interrelated nature of STEM concepts, the National Council of Teachers of Mathematics calls for a "shift in emphasis from a curriculum dominated by memorization of isolated facts and procedures and by proficiency with paper-and-pencils skills to one that emphasizes conceptual understandings, multiple representations and connections, mathematical modeling, and mathematical problem solving."[4] Educators looking towards K-12 as the key time to build STEM proficiency in students have begun to recognize that the various fields of engineering are a rich source of the types of "real-world" problems for K-12 mathematics and science education advocated by the National Council of Teachers of Mathematics[4] and the National Research Council[5]. The initiative discussed in this paper is an outgrowth of this recognition, and describes the use of engineering problems to demonstrate basic mathematical concepts.

In the spring of 2001, Georgia Institute of Technology received a grant from the NSF through its NSF Graduate Teaching Fellows in K-12 Education (GK-12) program to implement the Student and Teacher Enhancement Partnership (STEP) Program[6]. This program places 12 graduate students (STEP Fellows) per year into Atlanta-area high schools to help improve STEM performance of the high school students and to improve the leadership and teaching skills of the graduate students. During the first two years of the program, three STEP Fellows have directly assisted high school mathematics teachers with demonstrating specific math principles in algebra and trigonometry. Using their knowledge of engineering, the graduate Fellows developed hands-on approaches for mathematics education to provide a framework for the important uses of mathematics in engineering.

This paper will present techniques and activities designed to incorporate engineering concepts into high school algebra and trigonometry classes and will provide analysis of implementation with the high school students. The success of these activities in math classes demonstrates that laboratory activities should not be restricted to their typical role in science classes and that some traditional physics lab activities have independent value as hands-on mathematics lab activities. To effectively prepare students for overall STEM proficiency, the National Council of Teachers of Mathematics states "A variety of instructional methods should be used in classrooms in order to cultivate students' abilities to investigate, to make sense of, and to construct meanings from new situations; to make and provide arguments for conjectures; and to use a flexible set of strategies to solve problems from both within and outside mathematics."[4] Engineering activities support exactly this type of learning.

The organization of this paper is as follows. Section 2 discusses other efforts that incorporate engineering into the K-12 curriculum and the need to specifically address mathematics skills. Section 3 provides an overview of the Student and Teacher Enhancement Partnership (STEP) program at Georgia Tech. Section 4 presents the laboratory activities implemented in algebra classes and provides analysis of implementation with at-risk students. Section 5 presents the laboratory activity implemented in trigonometry classes and provides analysis of implementation with accelerated students. Finally, Section 6 summarizes the discussion on incorporating hands-on activities in the mathematics classroom.

2. Background

Initiatives to increase the use of engineering concepts within the K-12 classroom generally concentrate on medium to large instructional units to be implemented in physical science, physics, or pre-engineering courses. Both universities and professional societies have developed and promoted successful programs to incorporate engineering into K-12 classrooms. The Center for Engineering Educational Outreach at Tufts University offers a range of engineering activities and resources to help teachers meet technology and engineering frameworks[7]. Oklahoma University, through their Adventure Engineering Program, challenges students to develop solutions for scenarios requiring inquiry based learning, open-ended design, and target level math and science principles[8]. The American Society of Mechanical Engineers compiles the Best Practices in High School-Level Engineering Curricula to disseminate exemplary coursework, lesson plans, project activities, and technical curriculum through a network composed of high school teachers and engineers[9]. These efforts creatively expose K-12 students to the field of engineering hoping that through exposure, participating students will decide to enter engineering as a career. Mathematics learning-objectives are often covered, but tend to be the secondary motivation of the exercise.

Dr. Robert Moses, a noted proponent of addressing mathematics literacy, has developed the Algebra Project with the mission to help low income students and students of color – particularly African American and Latino/a students – successfully achieve mathematical skills that are a prerequisite for a college preparatory mathematics sequence in high school and therefore for full citizenship in today's technological society[10]. According to Dr. Moses, "Because the new technologies give rise to computers and an ever-widening use of symbol systems and quantitative data, we concluded that the schools and curricula we had to struggle to design *must* put mathematical and scientific literacy on a par with reading and writing literacy."[11] The contention of the current authors is that the field of engineering provides the type of examples that can appeal to all students and that can help provide them with the rationale of why mathematics is important. Hands-on engineering activities also provide the means by which teachers can meet the recommendations of the National Council of Teachers of Mathematics in regards to instructional pedagogy and content.

3. Student and Teacher Enhancement Partnership (STEP) Program

In 1999, the National Science Foundation initiated a new type of graduate student support through the NSF Graduate Teaching Fellows in K-12 Education (GK-12) program. Students receiving GK-12 fellowships are required to interact directly with K-12 teachers in an attempt to improve both K-12 education and the pedagogical and communication skills of the Fellows. In return, graduate Fellows receive an annual stipend and a tuition waiver. In the spring of 2001, Georgia Tech received a GK-12 grant to support its Student and Teacher Enhancement Partnership (STEP) program and to place twelve graduate students per year in Atlanta area high schools.

The broad goals of the GK-12 initiative and of the STEP program are:

(1) To broaden the education of science, technology, engineering, and mathematics (STEM) graduate students to include intensive experiences in educational pedagogy and process;
(2) To encourage the participation of STEM faculty and students in the difficult issues facing K-12 educators through the nurturing of university-school partnerships;
(3) To assist K-12 teachers in their endeavor to improve classroom instruction; and
(4) To help schools improve K-12 student achievement in STEM.

To address these goals, STEP forms partnership teams at each of six metro-Atlanta high schools that consist of two Georgia Tech graduate STEP Fellows, a teacher STEP coordinator, and additional teachers and administrators from the school. Each STEP team then designs an action plan for the year based on the needs of the school, and the talents and interests of the particular STEP Fellows. Three STEP Fellows have directly assisted high school mathematics teachers to develop hands-on approaches for mathematics education by using their knowledge of engineering to demonstrate specific principles in algebra and trigonometry. The laboratory exercises that follow are the result of this collaboration between engineering graduate students and high school mathematics teachers.

4. Laboratory Activities for Algebra

The National Council of Teachers of Mathematics states, "The proposed algebra curriculum will move away from a tight focus on manipulative facility to include a greater emphasis on conceptual understanding, on algebra as a means of representation, and on algebraic methods as a problem-solving tool."[4] In support of this curriculum standard, we developed and implemented laboratory activities at Marietta High School[12]. For the 2002-03 academic year, the school had approximately 1880 students with 588 ninth graders. The population was comprised of 44% African-American, 36% European-American, 15% Hispanic, and 5% other. About 12% of students had limited English proficiency and about 13% were in special education. The population of 9th graders enrolled in Algebra I was particularly at-risk for failure – during the two years prior to this project, 41 - 43% of the students failed to pass the course. To address this issue, the structure of 9th grade Algebra I was changed from a traditional, alternating day, block schedule to one where the students met every day in a block setting. This change doubled the instructional time for Algebra I, and required that teachers develop non-traditional activities to support the curriculum. The Algebra Laboratory activities developed by the STEP Fellows were designed to support this curricular change by specifically supporting and expanding upon the algebra topics of: (1) linearity and (2) systems of linear equations.

4.1 Linearity

The object of these activities was to reinforce the concepts of graphing, slope, and linear equations. These activities attached a physical meaning to the slope of the line after making observations about the relationships between the inputs and outputs.

<u>**Algebra Activity #1: Ohm's Law Lab**</u>

A conducting material obeys Ohm's Law when the resistance (***R***) between any two points is independent of the magnitude and polarity of the potential difference applied between those two points[13]:

$$R = \frac{V}{I} = \text{constant}\,, \quad (1)$$

In Algebra I, students learn the simple equation for a line:

$$Y = mX + b\,, \quad (2)$$

where ***m*** is the slope, and ***b*** is the y-intercept. Ohm's Law, when rearranged from Equation #1 above, provides a useful linear equation that is analogous to Equation #2:

$$V = RI\,, \quad (3)$$

where ***V*** is the voltage, ***I*** is the current, and ***R*** is the resistance. Therefore we used Ohm's law as the basis for a laboratory to demonstrate linearity.

To create this activity, we constructed a simple circuit that allowed the students to control the current (Figure 1). Using a voltmeter, the students measured the resulting voltage (***V***) across the resistor for different values of current (***I***) (Figure 2). This allowed the students to calculate the value of the resistance. The students plotted the voltages versus currents and calculated the slope of the line, which corresponds to the resistance value. A sample data sheet can be found in Appendix A.

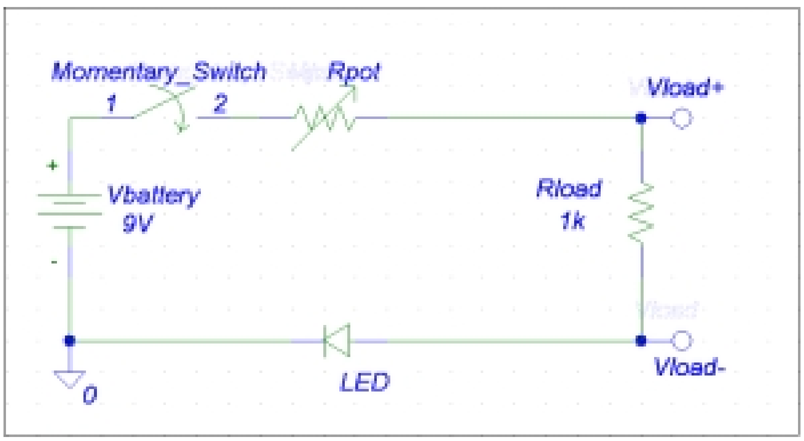


Figure 1: Circuit schematic for Ohm's law activity

Figure 2: Ohm's law apparatus with voltmeter

Lessons learned from Ohm's Law activity

This was the first exposure to an electrical circuit laboratory for the students. Overall, they performed extremely well once their anxiety about using electrical equipment was alleviated. Their graphs and data compared favorably to the expected measurements.

Algebra Activity #2: Hooke's Law Lab

As a second demonstration of linearity, we constructed an activity based on Hooke's law. To a good approximation for many springs, Hooke's Law states that the force ***F(x)*** exerted by the spring is proportional to *x*, the extension of the spring[13]:

$$F(x) = -kx, \quad (4)$$

To create this activity, we constructed a platform with a spring attached (Figure 3). The springs used had three regions: (1) a nonlinear region, (2) a linear region, and (3) a saturated nonlinear region. A 9.8N weight was used to set the spring into the linear region. First, the length of the spring was recorded with the 9.8N weight attached. The students then added weights to the spring (with the 9.8N weight still attached) and recorded the displacement of the spring. Students plotted the displacement (***x***) versus weight (***F(x)***) and calculated the slope of the line. The slope of this line was the spring constant ***k*** of the spring. A sample data sheet can be found in Appendix B.

Figure 3: Illustration of setup for Hooke's Law activity

Lessons learned from Hooke's Law activity

Overall, this lab worked extremely well. The students obtained excellent data without needing much (if any) assistance from the STEP Fellows or teacher. The only lesson for this activity was to prevent students from overloading the spring by borrowing weights from other groups. This would ruin the setup by causing the spring to perform in another region other than linear.

4.2 Systems of linear equations

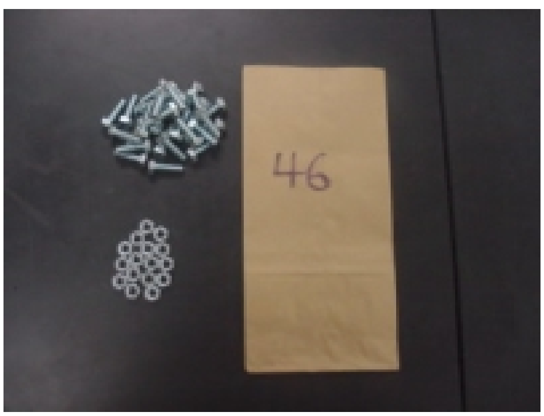
Both of these activities demonstrated how to solve mixture problems given certain information, such as the total number of pieces and an equation that relates the number of pieces to some measurements.

<u>Algebra Activity #3: Nuts and Bolts Lab</u>

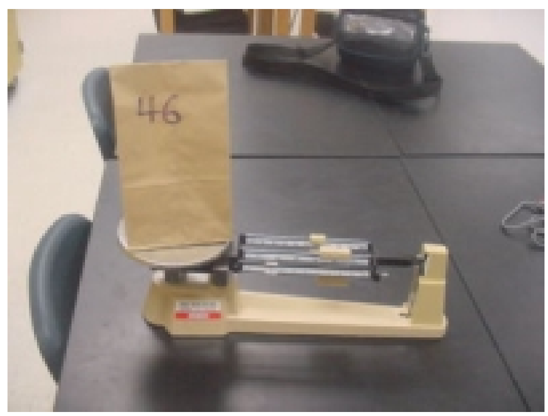
The students were given paper bags filled with both nuts and bolts (Figure 4a). The objective was to determine how many of each piece was in each bag given the total number of objects inside the bag. The students needed to measure: (1) the weight of the bag (both empty and full), (2) the weight of a nut, and (3) the weight of a bolt (Figure 4b). From this information, the students set up two equations relating the quantities of nuts and bolts and their total weight. Using the following system of equations, it was possible to determine exactly how many of each piece was in the bag:

$$\begin{aligned} N + B &= Total\ Number\ of\ Pieces \\ M_N N + M_B B &= Mass\ of\ nuts\ and\ bolts \end{aligned}, \quad (5)$$

A sample data sheet can be found in Appendix C.



(a) Lab components



(b) Measuring the weight

Figure 4: Illustration of equipment for the nuts and bolts activity

Lessons learned from Nuts and Bolts activity

Watch your wording. Here, we noticed that notational differences, using N and B and not x and y, caused some severe problems in the lab. The students were hung up on the notation and not what was the lesson at hand. This caused this lab not to run as smoothly as the other two and the students required more assistance. The teachers loved this activity and plan to incorporate it in the future using different candies rather than hardware.

Algebra Activity #4: Ohm's Law and Series Resistance Lab

The students were given a simple circuit with two sets of resistors in series (Figure 5) and asked to find the number of resistors in each set. The students were able to measure the voltage across each series resistance (Figure 6) and then determine the total resistance of the circuit. When the students were given the total number of resistors in the circuit and the values of the individual resistors, they were able to set up and solve a system of equations to determine how many resistors were present in each set:

$$R_{tot} = R_2\left(\frac{V_{high}}{V_{low}}\right)$$
$$R_1N_1 + R_2N_2 = R_{tot}\ , \quad (6)$$
$$N_1 + N_2 = N_{tot}$$

A sample data sheet can be found in Appendix D.

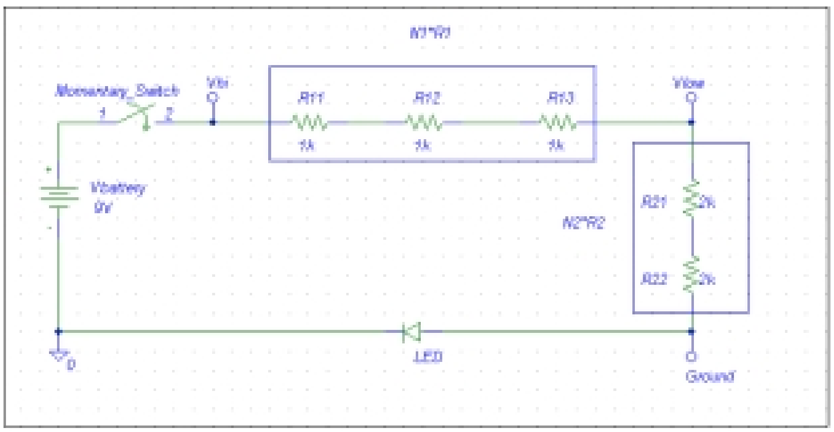


Figure 5: Circuit schematic for Ohm's law and series resistance activity

Lessons learned from Ohm's Law and Series Resistance activity

This activity was performed after the nuts and bolts activity - the reason being that the students can manipulate the bags and their contents while it is difficult for someone without a background in electronics to understand how to manipulate the circuit. The students saw this activity as being more abstract, since it is impossible to 'see' electricity. After making the connection between the previous Ohm's Law activity and this one, the students were more comfortable with the material. This activity required an extensive background talk about what resistance is and how it is used in this activity before the students could understand the meaning of the formulas given. From the teachers' standpoint, this lab was too theoretical because they lacked familiarity with electronics. As a result, this lab might have been more useful in a physics setting where the teachers have been exposed to the material.

(a) Lab components **(b) Measuring the resistance**

Figure 6: Illustration of equipment for Ohm's Law and series resistance laboratory activity

4.3 Evaluation of algebra laboratory implementation

The activities were conducted in the math lab and typically required about 30 minutes for each lab. The main algebra concept was introduced and connected to class lectures and assignments. Once the activities were tied to their class work, the procedure is outlined and demonstrated. Then the lab groups (usually 3 or 4 students) started the activity. The teacher and STEP Fellows facilitated the activity by: (1) answering any questions the students might have, (2) verifying the data was being properly collected, and (3) ensuring everyone was working on the task. Once all the groups finished, a summary of the lab and main concepts were presented.

These laboratory activities allowed the teachers to stimulate different learning styles while presenting mathematics concepts and to reinforce concepts previously covered in class. The teachers could gauge material retention by using these skills in an applied setting. As a preliminary test of the effectiveness of the laboratory activities, a teacher placed problems on the tests that mimicked the activities performed in the lab. On these problems, 80% of the students answered the question correctly despite the fact that overall, the students performed poorly on the exam.

The key lessons learned from the activities relate to discipline and motivation. Both are critical in a lab setting, particularly with the maturity of ninth graders. The teacher must be able to control their students in this less structured environment and relate the lab activity to the material presented in class. Otherwise the groups will get off task and use the time for socializing instead of learning. For example, a first-year teacher was known for having a 'rowdy' class. This teacher was quite lax towards controlling noise in the classroom, and it translated directly into the lab. This caused some severe problems because of the students' lack of respect toward both the teacher and us. These students never finished any of the activities we planned nor did they gain any additional insight by coming to the lab. In contrast, a former teacher of the year winner whose class had a great deal of respect for their teacher posed no disciplinary problems. With this class, the students were attentive, motivated, and on task the entire time. They often finished much sooner than we had expected. They also asked great questions and showed some intuition when thinking about the problem at hand. In addition, large class sizes become problematic resulting in more groups than normal and requiring extra lab resources for an activity.

5. Laboratory Activity for Trigonometry

The laboratory activity for trigonometry was developed and implemented at Druid Hills High School[14]. For the 2001-02 academic year, the school had approximately 1200 students. The population was comprised of 47.6% African-American, 37.7% European-American, 8.4% Asian-American, 3.1% Hispanic, and 3.2% other. About 15% of students were designated as gifted. The school used the 4x4 block scheduling (four classes per semester, covering the whole year's course in one semester) and offered trigonometry during the fall semester. The two trigonometry classes totaled 48 students, mostly designated as accelerated. The trigonometry teacher was interested in implementing some hands-on activities into the class to help reinforce the mathematical concepts. The following activity supported the specific concept of solving triangles.

5.1 Solving triangles

The object of this activity was to reinforce techniques for solving triangles using the context of a load-bearing structure. This provided a practical application for finding all the unknown sides and angles.

<u>Trigonometry Activity: Boomilever Lab</u>

The Boomilever laboratory was based upon the competition from Science Olympiad in which students design, construct, and test a triangular structure made from balsa wood[15]. The Boomilever is a cantilevered wooden structure that attaches to a vertical testing wall to support a load at the distal end. The specifications of the Boomilever apparatus followed the official rules from the Science Olympiad competition. Students produced original schematics of their apparatus design and constructed the apparatus for testing (Figure 7). The students competed for the best Boomilever structural efficiency as described by the following formula:

$$\text{structural efficiency} = \frac{\text{load supported (g)}}{\text{mass of Boomilever (g)}}, \quad (7)$$

The students were required to write a lab report that included the following sections: (1) Purpose and Background, (2) Pre-testing Diagrams, (3) Description of Construction, and (4) Conclusion. In the pre-testing diagrams, each group was responsible for solving angles and lengths required for construction (Figure 8). Skills reinforced included basic trigonometric functions as well as Laws of Sines and Cosines for designs using acute triangles. A full project description can be found in Appendix E.

Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition

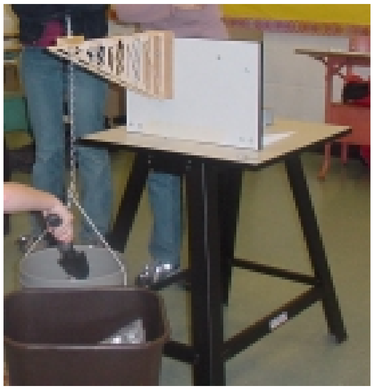


Figure 7: Illustration of testing a Boomilever apparatus

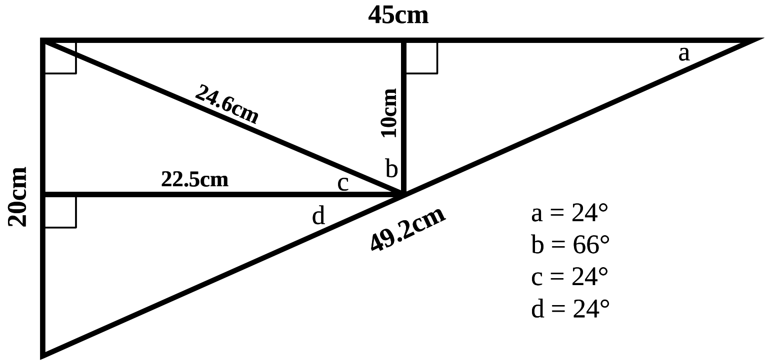


Figure 8: Sample side view of Boomilever apparatus with solved triangles

Lessons learned from Boomilever activity

Several key lessons were learned from the Boomilever activity. Implementing a team design project in a high school setting requires the full support of the teacher. Students who normally are used to individual assignments will get an introduction to "real-world" scenarios. Also, students will perform at the milestone pace, so you can be more aggressive with the target deadlines. In addition, it is essential that trigonometric principles are not lost in the project implementation. Overall, the teacher thought the activity was valuable and planned to use it again in subsequent years.

5.2 Evaluation of trigonometry laboratory implementation

The Boomilever activity was implemented as an engineering design project with milestones. The intermediate goals with corresponding due dates ensured that each team, comprised of 4 students, progressed through each required phase of the activity. For the project introduction, students were given an overview of some basic physics concepts (force, equilibrium, etc.) and their relationship to trigonometry. The subsequent milestones of the project are given in Table 1.

Table 1: Boomilever laboratory activity milestones

Project Milestone	Time Allocated
Boomilever Schematic Drawing	1 week
Boomilever Apparatus Construction	2 weeks
Lab Report	1 week

The Boomilever activity allowed students to creatively explore trigonometric principles through the unique design of their apparatus. One requirement of the lab report was to analyze the performance of their apparatus. Students enjoyed constructing and testing their apparatus and were motivated by the design competition. The activity also presented a creative method to enhance the trigonometry class by providing students with a precursor connection to physics.

6. Summary

Engineering concepts can be incorporated into the mathematics curriculum to demonstrate concepts in both algebra and trigonometry. Three graduate students of Georgia Tech's Student and Teacher Enhancement Partnership (STEP) program directly assisted high school mathematics teachers to develop the hands-on activities described in this paper. The experiences of the STEP Fellows in the classroom have led to the following observations:

- The teachers must relate the lab activity to the material presented in class. This provides background knowledge that the students can use to relate to the problem at hand. It also emphasizes the applied aspect since students are able to relate the concepts learned in class to the activity.

- It is necessary to have a metric to evaluate the effectiveness of these activities. Incorporating similar problems into tests or using the labs as test grades serve two purposes: (1) it provides some feedback as to how well the students understood the activity (and associated mathematic concept) and (2) it provides motivation since students want good grades.

- Planning is required to properly incorporate activities into the lesson plan. Developing an effective activity is a time-consuming process. Teachers must determine when they will cover important topics well in advance of when they want to perform an activity and allocate the required class time. This maintains continuity in the presentation of mathematics concepts.

Ultimately, our hope is that incorporating engineering activities into mathematics classes will help improve student academic performance in those classes. At Marietta High School, we will continue to develop and implement engineering activities in the Algebra Laboratory, and will monitor student success in these classes. Preliminary evidence from one classroom exam suggests that students retain algebra concepts better when they are reinforced through hands-on activities. However more quantitative evaluation must be done to determine the ultimate effectiveness of the activities. At the current time our evaluation is based strictly on observation and teacher comments. This qualitative evidence from our implementation of engineering activities suggests that laboratory activities should not be restricted to their typical role in science classes, but can enhance the instructional methods used in math classes. The activities reinforce classroom concepts and enable students to connect the importance of mathematics with today's technologically oriented society.

7. Acknowledgment

The Student and Teacher Enhancement Partnership (STEP) program at Georgia Tech is supported through the NSF Graduate Teaching Fellows in K-12 Education (GK-12) program under NSF Project Number DGE-0086420.

The authors would like to thank the mathematics departments at both Druid Hills High School and Marietta High School who encouraged the development and implementation of mathematics laboratory activities in their classrooms. The authors also acknowledge the invaluable service of Pamela Chinik, STEP Coordinator at Druid Hills High School, and Marsha Shrago, STEP Coordinator at Marietta High School.

8. References

[1] R. P. Moses, "Remarks on the Struggle for Citizenship and Math/Sciences Literacy," *Journal of Mathematical Behavior*, vol. 13, pp. 107-111, 1994.
[2] H.-Z. Ho, D. Senturk, A. G. Lam, J. M. Zimmer, S. Hong, Y. Okamoto, S.-Y. Chiu, Y. Nakazawa, and C.-P. Wang, "The Affective and Cognitive Dimensions of Math Anxiety: A Cross-National Study," *Journal for Research in Mathematics Education*, vol. 31, pp. 362 - 379, 2000.
[3] "Testimony of Chairman Alan Greenspan," in *Committee on Education and the Workforce, U.S. House of Representatives*. Washington, D.C., 2000.
[4] National Council of Teachers of Mathematics, *Curriculum and Evaluation Standards for School Mathematics*, 1989.
[5] National Research Council, *National Science Education Standards*. Washington, D.C.: National Academy Press, 1996.
[6] D. Llewellyn, M. Usselman, and G. Kingsley, "The Georgia Tech Student and Teacher Enhancement Partnership (STEP) Program: A Set of Models of Graduate Students Working in High Schools," in *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition*, Montreal, Canada: American Society for Engineering Education, 2002.
[7] Center for Engineering Educational Outreach at Tufts University, http://www.prek-12engineering.org.
[8] Oklahoma University, Adventure Engineering Program, http://coecs.ou.edu/aeweb/.
[9] American Society of Mechanical Engineers, http://www.asme.org/education/precollege/bestpractice/bp.htm.
[10] Algebra Project, http://www.algebra.org/index.html.
[11] R. P. Moses and C. E. Cobb, *Radical equations : math literacy and civil rights*. Boston: Beacon Press, 2001.
[12] Marietta High School, http://www.marietta-city.k12.ga.us/mhs/index.asp.
[13] D. Halliday and R. Resnick, *Fundamentals of physics*, 3rd ed. New York: Wiley, 1988.
[14] Druid Hills High School, http://www.dekalb.k12.ga.us/~druidhills/.
[15] Science Olympiad, http://www.soinc.org/.

Appendix A – Algebra Activity #1

Data Sheet: Ohm's Law (with sample data included)

Name: ____

Class and Teacher: ____

Date: ____

Data Table:

Setting	Current (mA)	Voltage (V)
0	0	0
1	1.30	0.65
2	1.50	0.75
3	2.00	1.00
4	3.50	1.75
5	5.00	2.50
6	7.30	3.65

Instructions:

1. Set the dial to setting 1. Press and hold the button and record the voltage.
2. Set the dial to setting 2 and record the voltage.
3. Continue for all of the settings.
4. Plot the voltage versus the current and determine the slope of the line. Multiply this number by 1000 and record it.

Appendix B – Algebra Activity #2

Data Sheet: Hooke's Law (with sample data included)

Name: ____

Class and Teacher: ______________________________________

Date: ____

Instructions for each group:

1. Measure the position of the spring with the 9.8N weight attached. Add another weight to the spring and record the resulting position. From these two points, it should be possible to calculate the slope (in this case, the slope is the spring constant).
2. Once the slope has been determined, find the equation of the line. Half of the group should use the slope-intercept form and the other half should use the point-slope form. Compare the two equations. What are their differences?
3. Check with the teacher or lab supervisor to ensure that your equations are correct.
4. For the table on the data sheet, predict *d* for each weight using the equation you obtained in part 2.
5. Obtain the necessary materials to measure the positions of the springs for the given weights.
6. Plot your data and the line on the same graph. How well does this line fit your data?

Data Table:

Weight: *9.8N* Position:__________*70cm*__________________

Weight: *14.70N* Position:__________*75cm*__________________

Slope:_____1.02 cm/N________

Equation of the line:___*P = 1.02W + 60*______________________ (check with teacher)

Weight (N)	Predicted Position (cm)	Actual Position (cm)
11.76	72	72
16.67	77	76
19.60	80	80
21.56	82	83

Appendix C – Algebra Activity #3

Data Sheet: Nuts and Bolts (with sample data included)

Name: ____

Class and Teacher: ____

Date: ____

Instructions:

1. Measure the mass of one nut
2. Measure the mass of one bolt
3. Measure the mass of the bag with the nuts and bolts
4. Subtract the mass of the empty bag from the mass of the full bag and record
5. Solve for N and B – recall that N and B must be either positive or zero.

$$N + B = Total\ \ Number\ \ of\ \ Pieces$$
$$M_N N + M_B B = Mass\ of\ \ nuts\ and\ bolts$$

Data Table:

Mass of a single nut:_________*4.7*_________________ g. This is M_N.

Mass of a single bolt:________*12.8*_________________ g. This is M_B.

Mass of the bag (empty):_______*8.0*_______________ g

Mass of the bag (full):_________*296.8*________________ g

Mass of the nuts and bolts = mass of full bag – mass of empty bag = ________*288.8*_______g

Total number of pieces in the bag = ____________*30*________________

Solution:

N = *12*
B = *18*

Appendix D – Algebra Activity #4

Data Sheet: Ohm's Law Systems of Equations (with sample data included)

Name: ____

Class and Teacher: ____

Date: ____

Instructions:

1. Measure the two voltages and record them in the table
2. Calculate R_{tot}
3. Determine N_1 and N_2 – recall that these must be either zero or positive

$$R_{tot} = R_2\left(\frac{V_{high}}{V_{low}}\right)$$

$$R_1 N_1 + R_2 N_2 = R_{tot}$$

$$N_1 + N_2 = N_{tot}$$

Data Table:

Circuit #	R1	R2	R_{tot}	N_1	N_2	N_{tot}	V_{low}	V_{high}
1	1	10	23	3	2	5	0.333	7.68
2	100	150	1300	4	6	10	0.863	7.50
3	100	270	570	3	1	4	3.43	7.82
4	3.3	4.7	20.7	2	3	5	1.74	7.64
5	39	15	240	5	3	8	0.525	7.84
6	10	470	570	10	1	11	6.15	7.48
7	68	820	4440	5	5	10	1.46	7.92
8	220	560	4580	3	7	10	0.922	7.58

Appendix E – Trigonometry Activity

This project will consist of two parts:

(1) Boomilever Apparatus and Performance 40 points
(2) Lab Report with diagrams 60 points

The specifications of the Boomilever apparatus will follow the official rules from the Science Olympiad competition. The best Boomilever structural efficiency will receive the maximum 40 points. All others will have up to ten points deducted from the apparatus portion of the assessment based upon their structural efficiency ranking.

There will be one lab report per group with contributions from everyone in the group.

Lab Report Requirements

Each **typed lab report** will consist of:

A. Purpose and Background
   - Include the goal you are trying to accomplish and describe some related concepts (cantilever, trigonometry, force, equilibrium, etc.).

B. Pre-testing Diagrams
   - Include front, top, and side labeled diagrams of your apparatus before testing with measurements for each view; use the measured lengths to calculate and label the corresponding angles formed within the apparatus.

C. Description of Construction
   - Describe the reason for any technique or geometry that contributed to your design; this should demonstrate the originality of your design instead of just building one of the examples.

D. Conclusion
   - Report the results of the apparatus testing (apparatus mass, load supported, calculated structural efficiency).
   - Describe the forces that were acting on your apparatus during testing.
   - Discuss how your apparatus performed relating the concept of load to the geometry used in your design. Was it successful, why or why not?
   - Using what you have observed and learned, describe any improvements that you would make to your Boomilever apparatus.

Boomilever Assessment

<table>
<tr><th colspan="3">Project Section</th><th>Points Received</th></tr>
<tr><td colspan="2">Apparatus</td><td>40 points</td><td></td></tr>
<tr><td rowspan="4">Lab Report</td><td>Purpose and Background</td><td>10 points</td><td></td></tr>
<tr><td>Pre-testing Diagrams</td><td>15 points</td><td></td></tr>
<tr><td>Description of Construction</td><td>10 points</td><td></td></tr>
<tr><td>Conclusion</td><td>25 points</td><td></td></tr>
<tr><td colspan="3">Total Points</td><td></td></tr>
</table>

Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition

WILLIAM H. ROBINSON
Mr. William H. Robinson is a doctoral student in Electrical and Computer Engineering at Georgia Institute of Technology. His research interests include parallel computer architectures for image processing and VLSI design. He is a 1996 National Science Foundation Graduate Fellow and a 2002 Ford Foundation Dissertation Fellow. He is a member of the IEEE, ASEE, and NSBE. William is a STEP Fellow from the 2001-02 academic year.

ADAM O. AUSTIN
Mr. Adam O. Austin is a doctoral student in Electrical and Computer Engineering at Georgia Institute of Technology. His research interests include intelligent systems, hybrid systems, and behavior based robotics. He is also a member of IEEE. Adam is a STEP Fellow from the 2002-03 academic year.

DEMETRIS L. GEDDIS
Mr. Demetris L. Geddis is a doctoral student in Electrical and Computer Engineering at Georgia Institute of Technology. His research interests include integrated optoelectronics, optical communications, and microelectronics. He is also a member of IEEE. Demetris is a STEP Fellow from the 2002-03 academic year.

DONNA C. LLEWELLYN
Dr. Donna C. Llewellyn is the Director of the Center for the Enhancement of Teaching and Learning (CETL) and an adjunct associate professor in Industrial and Systems Engineering at Georgia Institute of Technology. Her current areas of research are in equity of engineering education, and assessment of instruction. Donna is the PI of the STEP NSF grant.

MARION C. USSELMAN
Dr. Marion C. Usselman is a Research Scientist at the Center for Education Integrating Science, Mathematics and Computing (CEISMC) at Georgia Institute of Technology. Marion received her Ph.D. in biophysics from Johns Hopkins University and has taught in the Biology Department at the University of North Carolina, Charlotte. She focuses on equity issues in education and K-12 educational reform. Marion is a co-PI of the STEP NSF grant.