GEOMETRY AND MATHEMATICS THROUGH BRIDGE BUILDING

J. JOYNER
Norfolk City Public Schools, Norfolk, Virginia
jjoyner@norviewhs.nps.k12.va.us

I teach mathematics at Norview High School, one of five high schools in the Norfolk City public school system. The school population is made up of approximately 1,700 students from middle- to low-income neighborhoods. The ethnic mix of the student body is approximately 70% Black, 25% White, and 5% Other (principally Filipino). I have been teaching in public schools for six years after an eighteen-year career with the United States Navy. In those six years, I have taught almost every math subject offered at the high school level in the Norfolk Public School system.

Early in my second year of teaching, the school system's senior coordinator for mathematics asked me if I would be interested in teaching an inaugural *Mathematics Through Bridge Building* class for gifted middle school students in the Extended Day Program. Since I have always tried to help students make connections to real-world uses of mathematics, this course appealed to me; however, I knew little about both bridge building and teaching elementary engineering concepts. Fortunately, the Virginia Beach Public Library proved to be a treasure chest of books on bridges—many written for school-age children. With two weeks' preparation under my belt, I began teaching the bridge building class and have continued to do so for the last five years.

Middle school students who wish to take enrichment classes attend the Extended Day Program. The subject matter of the classes goes beyond the scope of what is available to them at their current grade level. Students must apply and be accepted into the program and their parents must pay a small fee for their participation in each class. Most of the classes meet one afternoon per week for two hours over the course of several weeks. Though we originally met for eight weeks, the *Mathematics Through Bridge Building* class now runs for ten weeks.

The bridge building class is always an exciting experience; the students are inquisitive and energetic, and each class is unique. Every year I learn more about the subject matter through researching and preparing for class. I do think, though, that I learn more from my students than I teach them. Now, that's fun! Because each year's class ranges in size from eight to sixteen

The Journal of Mathematics and Science: Collaborative Explorations Volume 3 No 2 (2000) 39-46

students, the dynamics change not only from year to year, but also from activity to activity. Overall, the students have reacted positively to the math, engineering, and physics principles to which I expose them. I combine these three principles with video, computer, and hands-on activities, then stand back and watch as the students become "detective engineers." There is no single activity that I do in class that has more student enthusiasm than the application of geometry and bridge construction concepts to the building project. The project requires after-school time and students who otherwise do not come for after-school help in geometry will wait in line, if necessary, to use one of eight classroom computers.

As I stated before, each year the class content evolves. I am constantly searching for new activities and for ways to modify current activities to encourage student involvement. I firmly believe in the appropriate use of technology in the classroom; this course is no exception. Bridge building activities may require anything from simple paper and pencil or poster board for designing and building, to internet connections and computer software. My greatest concern is the lack of resources available given the number of students served. While group work is useful for certain activities, it would be beneficial if each student could individually explore his or her ideas, then share the results with the larger group.

The program has no formal assessment. Classes in the Extended Day program are not graded, but the excitement and enthusiasm displayed by the students affirm my belief that what I hope to achieve is taking hold. I simply want students to develop and experience a concept of math that is positive, as well as applicable to their lives.

Most teachers may not have the opportunity to offer such a set of activities in a non-traditional classroom setting such as the Extended Day Program. For teachers who wish to offer a project or extended activity in a regular classroom, I have included a brief overview of how I have structured my bridge building activity in my second semester geometry classes. Teachers who wish to use my overview may change anything and everything in it to suit their individual needs, resources, and desired outcomes.

The budget for the bridge building course is fairly minimal, with funding coming through the Norfolk Public Schools Gifted Center. Also, I have personally purchased items to use in class, but this has always been my own decision. Not every activity or resource is used each year in the bridge building class. Resource items range from poster board, scissors, tape, staples, and graph paper to Legos kits, Knex bridge kit, and Bridge Builder software [1,2]. The most expensive items I use are the Knex comprehensive bridge kit (currently $140, but smaller basic kits are available for less) and the Bridge Builder software (currently $99 for a single license with lab, school, and network packs available) [1,2]. Funds to support a bridge building activity or project may be available within individual schools and districts, and also through grants, government sources or education foundations. You may obtain additional information by e-mailing me.

The Idea

Students are exposed to a practical use of geometry through the research, design, simulated construction, and testing of a truss bridge. The basic engineering principles behind a truss are easily understood since it is based on the simplest type of polygon—the triangle.

General background information is available – even in school libraries with few engineering-specific resources. Encyclopedias contain descriptions, histories, and the various uses of the truss. Public libraries are likely to have even more engineering-specific resources, such as civil engineering books, for students and teachers. There is a wealth of information on the World Wide Web. Schools of civil engineering at universities and colleges, as well as individuals with an interest in bridge construction, post many of these sites. Most of the sites include photographs and other graphics, some of which are interactive. These bridge sites are generally more current than information available to students in printed form and many are geared to students or other laypersons.

This project is conducted in three phases over a period of approximately three weeks. Most work is done outside the classroom. In phase one, students prepare a one-page summary of their research on trusses. They submit it to me for a quick review to ensure that they have the basic concepts of what a truss is and how it is used.

In phase two, students design a simple, two-dimensional truss bridge on graph paper. The bridge must meet the dimensional criteria of building a truss bridge using the software Bridge Builder (Pre-Engineering Software). The bridge must span a 400-foot body of water, rise no more that 100 feet above the roadway, and extend no more than 65 feet below the roadway. Other basic criteria, such as the maximum allowable length of a building member (box girder), maximum number of members allowed, and maximum number of joints allowed, must be used by each student in the graph paper design of the bridge. At this phase of the activity, students bring to play their knowledge of triangles (types, properties), symmetry, and aesthetics in designing their bridges. The graph paper design is also submitted to me for a quick review. I check to see that each student has met the basic design criteria, and whether each has used a scale to aid in the simulated construction of the bridge in. the final phase. I encourage each student to be as thorough as possible in the graph paper design of the bridge as this will make the final phase of activity easier. Since I can't tell if a student's design will work or not by visual inspection alone, I ask questions to ensure that each student has properly considered or used the various design concepts and requirements. Some designs look more promising than others, but it is not until the bridge is actually constructed on the computer, and then tested, that a student knows if a design will work.

In the final phase. students "construct" their graph paper-designed bridges using Bridge Builder software. This software package is designed specifically for students in grades six through twelve and is easy to use. Once constructed on the computer, each student tests his or her bridge. The first test is a static—dead load—test to see if the bridge will support its own weight. The second test is the dynamic—live load—test to see if the bridge will support a forty-ton truck that is driven across the bridge on the computer monitor. The first test must be passed before the second test can be run. If either test fails, the student must analyze his or her design and reconstruct the bridge until it passes both tests. Once a successful bridge is "built," each student must then improve the design or construction to increase the overall efficiency rating of the bridge.

The Outcomes

The project in *Mathematics Through Bridge Building* allows students to use their knowledge of line segments, angles, triangles and polygons, proportions, symmetry and reflection, aesthetics, and basic engineering principles associated with trusses. Students are exposed to basic schematic drawings through the printed copies of their bridges produced by the software. Each student reviews the basic analysis of his or her bridge as printed out by the software. That analysis contains basic information. such as the wire diagram of the bridge. the length and angle of each member in the bridge, the amount of compression or tension in each member. the efficiency of each member, as well as the overall efficiency of the bridge.

In addition to using and reinforcing research skills, students make use of practical geometry skills, graphing skills involving the use of scales and proportions, computer skills through the use of the Bridge Builder software, and analytical reasoning skills in testing and improving the designs of their bridges. Although the application of engineering and physics formulas is not required of the students in computerized construction and testing of the bridges, students are exposed to those basic principles and to the fact that the software is using engineering and physics formulas in its testing and analysis printout.

Evaluation

As indicated above, student progress is assessed at three points along the way: when the research summary is submitted; when the graph paper design is submitted; and, when the bridge construction is successful, and then improved. A copy of the project sheet that each student is given appears as an appendix.

References

[1] Knex Education Web Page, http://www.knexeducation.com

[2] Pre-Engineering Software Corporation Web Page, http://www.pre-engineering.com

APPENDIX

Geometry B End of Semester Projects
Mr. Joyner

Name: ____ Date: ____________
Choose one of the following special projects to do. The project will count as a **double project grade**. If you choose to do both projects, indicate which is the primary project; the other project will count as a **bonus project grade**. The project must be turned in no later than June 8, 1999.

1. Bridge Building

a. Research what a **truss** is in engineering and explain how it is used in building bridges. Your explanation must be coherent, use correct grammar, and be at least one page (typewritten). Cite all references used. If you do not cite references used, no points are earned. (20 points)

b. "Design" a truss bridge on **graph paper** using the requirements of the **Bridge Builder software**. "Construct" and test your bridge using Bridge Builder, which is available on the classroom computers. Once your bridge passes all tests, print the bridge's engineering data. Save the bridge to floppy disk. (60 points)

c. **Improve the design** of the bridge to get a lighter and more efficient bridge. Print the bridge's engineering data. Save the bridge to floppy disk using a similar name. (20 points)

Initial Efficiency	**Final Improved Efficiency**	**Points Earned**
Less than 30%	Less than 50%	10
Less than 30%	More than 50%	14
More than 30%	Less than 50%	17
More than 30%	More than 50%	20

2. Geometry in Art, Architecture and Engineering

a. Find an artist, architect or engineer, or a style of art, architecture or engineering that makes strong use of geometric shapes. Research the subject as well as the design layout of several newspapers. Create a **newspaper "front page"** on posterboard that tells the story about your findings. Your newspaper must have a title, as must your article. The front-page story must include at least three graphics. The story must be coherent, use correct grammar, and be at least 400 words in length (typewritten).

Category	**Points Possible**
Newspaper Title	5
Appropriate Article Title(s)	5
Newspaper Design Layout	10
Appropriate Use of Graphics	15
Article(s) Content and Presentation	65

INTERVIEW WITH JOSEPH JOYNER

Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?

A: I never intended to become a teacher when I was in college. I tutored when I was in college, but that was as close as I came to any sort of teacher preparation. When I graduated, I had taken no education courses. It was a few years later that I had the opportunity to become a classroom teacher for an adult education program. I fell in love with teaching during that first week! A year later, I had been offered a faculty position at a community college in the City University of New York. For three years, I was a co-director of the math lab at Bronx Community College. While there, I took my Master's degree in mathematics education, while also teaching classes at Bronx Community College and Lehman College. Shortly after I got my master's degree in early 1976, I joined the U. S. Navy (this had been on a back burner) as an officer. So began an eighteen year break in my short teaching career. I knew that when I eventually left the Navy that I would return to teaching. When the time came to end my Navy career, I took all of the courses needed to get a Virginia teacher's license. I walked out of the Navy and directly into the classroom at Norview High School in 1994 and am there today. So, yes, there were many twists along the way.

Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?

A: My first involvement in a program of this nature was in December 1995. I had just finished my first year of public school teaching, and I was asked by the mathematics coordinator for Norfolk Public Schools to considered teaching a *Mathematics Through Bridge Building* class to middle school students as part of the after-school program for the school system's Gifted Center. I said yes, despite not having any background as an engineer or any resources to teach the course. That first course was fun for me—an adventure. I gave a workshop presentation of the bridge building course at the Virginia Council of Teachers of Mathematics annual conference in Charlottesville in 1997. I have taught the class for five years now and each ten-week offering has been different than the ones before it. I am now scheduled to teach the course in a new summer enrichment program for the school system's Gifted Programs Office.

Q: Have there been any unique or unexpected consequences for you resulting from your project?

A: No, not really, other than I think I learn more than I teach the kids and perhaps have more fun at it too! I am told that the course is a very popular one now in the Gifted Center's Arts and Sciences Program.

Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on *Mathematics Through Bridge Building*? What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?

A: The greatest lesson that I have learned is that if you can unleash a student's creative imagination, then learning will happen. I have seen students who perhaps were interested in little else in geometry come alive with this project. I have had geometry students standing in line after school waiting to use computers in the classroom in order to work on this project. The greatest benefit is that real learning happens and doesn't have to be forced. Perhaps through exposure to projects like these, teachers will have ideas for other projects that can similarly capture the creative imaginations of students—once that happens, stand back and watch the students take off! Projects take time and sometimes are hard to fit into a curriculum that may be focused on standardized test scores. But if they are productive and can be made to fit, the benefit is well worth it. I need more like this one in all of my classes!! I'm searching.