Science and Engineering Models in Middle School

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Abstract

Science and engineering models are used to create enthusiasm among middle school students. They have been implemented as enrichment activities in regular classrooms and as special projects in math clubs designed to encourage greater participation of women in math, science and engineering. The models have formed the basis of a course offered to practicing teachers and also have been presented at teacher workshops. Lesson plans have been designed for different topics. Teacher feedback and assessment are considered an important aspect of this development program.

Introduction

This paper describes a set of science and engineering models used by the authors in K-12 classrooms. The models have been used as enrichment activities in regular classrooms and also as special projects in math clubs designed to encourage greater participation of women in math, science and engineering.

The models have also formed the basis of a course offered to students taking a master of mathematics for teachers' degree. Students (teachers) learn some of the mathematics and physical principles behind each model, together with lesson plans for the use of each model in K-12 classrooms. The plans include a correlation to the local, state, and national curriculum. A manual is being prepared, which includes the engineering and mathematical descriptions of the models as well as the lesson plans.

An earlier presentation[1] provided an overview of the teacher class and lesson plans. This paper provides some more detail of the models and their use in math lessons. The results of teacher assessment and follow up are also discussed.

The Models

Projectile Motion

The path of a projectile may be described by a series of equations. Using these equations, it is possible to determine the location, velocity, acceleration, and time of flight of the projectile at any point in its trajectory. The arc of a projectile is dependent on two variables: initial velocity and angle of ascent. The concepts of velocity and acceleration as well as angle measurements can be covered in detail here. Lesson plans include throwing of different objects, path of toy cars dropping off a ramp, and video clips of projectile motion in sports.

Introduction to Fractals

The mathematics underlying much of fractal imagery involves iteration of functions defined on the complex plane. Some simple calculations in complex variables can be performed by students and the concepts of periodic orbit and self-similarity can be explained to them. Computer images of fractals and their algebraic and geometric patterns can be displayed. Lesson plans include the construction of Koch snowflakes and fractal trees. The measurement of area and perimeter for these shapes provides a review of geometry concepts.

Topographic maps

Contour maps represent three dimensional data on a two dimensional plane by joining together points of equal height. Surfaces given by mathematical equations can be displayed in this way. Students learn to visualize in three dimensions and review the concepts of scale and measurement. Lesson plans include construction of the surfaces with play-do and Lego cubes. Surfaces are also created from function tables.

Electricity

Three of the basic terms used in studying electricity are voltage, current, and resistance. Voltage is the potential for movement of electrons. Current is the rate at which the electrons travel and resistance is the ability to reduce the current or slow down the electrons. Ohms law is used to study circuits and shows the relationship between voltage, current, and resistance. The relationship between resistors arranged in series or in parallel is given by

$$R_T = R_1 + R_2 + R_3$$

and

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

respectively. These equations provide a rich opportunity to understand the concepts of inverse and fraction addition. Lesson plans include construction of a closed circuit with bulbs and resistors and a deduction game based on hidden magnets.

Compost

Composting, which allows certain organic wastes to decompose into a rich fertilizer, is an environmentally friendly option for the recycling of waste Wastes that can be included in a compost pile include yard wastes, fruit and vegetable scraps, and old newspapers. Two common types of composting are outdoor composting and worm composting. The rate of decay of organic materials can be modeled by a differential equation. Lesson plans include a school compost bin and an analysis of the amount of waste in fast food takeaways. These lessons involve review of volumes and decay rates.

Spider web geometry

The spider web displays a nice level of symmetry. Figure 1 shows a typical web, with eight rays and four sectors. Each ray is 45^0 from the next ray. Each sector is one unit from the next. The concept of polar coordinates can be used to identify all the intersection points of rays and sector lines in the web.

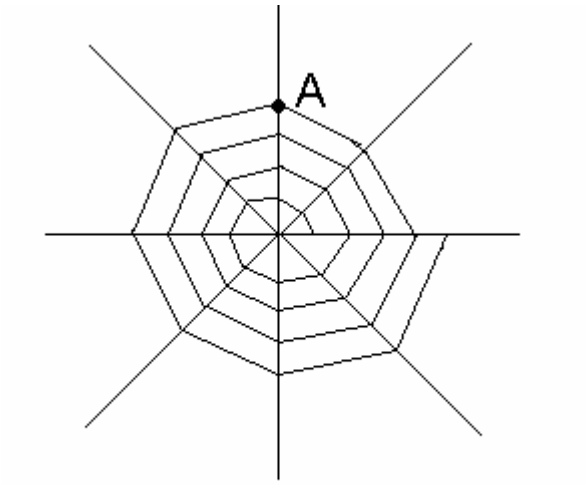

Figure 1

A number of concepts from elementary geometry are useful in developing lesson plans based on the spider web. Lesson plans involve measurement and classification of angles, construction of a web from yarn, and a bingo type game based on grid points.

Glaciers

A glacier is a mass of frozen matter, mostly ice, formed from packed snow and accumulated over several years. Much of the world's freshwater is actually contained in glaciers. The

melting of glaciers is important since it leads to an increase in sea level, cooling of sea temperatures and increased numbers of floating icebergs. Glaciers usually move slowly down mountain valleys and portions drop off (calf) in the form of icebergs. Additions of new snow lead to *accumulation* and loss (melting) of ice is described as *ablation.* Much of the scientific study of glaciers involves simulation of their movement and melting patterns. Internal deformation of the glacier and sliding along its base are the primary forms of glacier movement.

Simulations of glaciers on a small scale in a classroom depend on properties of water such as its density. Phase diagrams can be introduced. Lesson plans involve the creation of glaciers from popsicles, and also from a mix of ice and gravel. Melting of ice in water provides an opportunity to review density and volume concepts.

Observations

The lesson plans were developed by teachers attending a course on mathematical modeling at the University of Tennessee. The course was taught by the authors, with assistance from a local district curriculum specialist. Many of the lessons have been described in teacher workshops and have been implemented in middle school classrooms.

Middle school students enjoy hands-on activities. Some of the lessons create greater interest than others. The spider web bingo game was one of the most exciting classes the authors have ever observed. The electrical circuit lesson was very popular. The creation of the three dimensional surface posed some challenges as many students tried to create it on the two dimensional plane only. The melting glacier model requires several days and careful monitoring to be an effective simulation experiment.

Assessment

Teachers were assessed by regular exams and project work during the duration of the course (or workshops). At this level much of the mathematics was beyond them. Concepts in trigonometry and differential equations were accessible only to a few. Some teachers just seemed to want the lesson plans but didn't approach the scientific background with a great sense of curiosity. Several teachers were enthusiastic in their design of lesson plans. Others tended to rely on standard lessons found on Internet web pages. Some teachers tried the lessons in their own classrooms and were able to use the feedback to improve the quality of the lessons. Teachers need great vision and support if they are to be willing to utilize enrichment activities at the expense of regular instruction time. In one of the workshops teacher surveys revealed the greatest interest in the fractal model with the contour maps in second place. There was also a difference in attitude depending on whether teachers had a middle school or high school teaching background.

The middle school students were generally pleased to participate. They are often focused on tests and these lessons were a break for them. The models were used especially in two focused

studies. One was in specific inquiry based projects, where hands-on activities are ideal. The other was in girls-only math clubs. Many of these girls had been unaware of careers in engineering or what that might entail. The latter group developed confidence and knowledge of engineering areas that have traditionally been male dominated. However, the activities were not sufficient to convince these young women that mathematics was a creative activity or that a career in mathematics would be interesting.

Conclusion

A series of engineering and science lessons have been developed to increase student interest in these areas at the middle school level. Limited teacher and student participation has generated much enthusiasm. There needs to be further testing and fine tuning of the lessons followed by publication of a manual to make these available over a wide geographic region. Teacher and student observation should yield more insight into lesson design and student surveys can assess the impact on learning and increased enthusiasm for engineering topics. There is potential to develop the lessons to a level well beyond the middle school. The authors have successfully accomplished this for one lesson where they have used the play-do representations to assist in the teaching of two dimensional calculus[2].

References

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Dr. Dwyer is an assistant professor of mathematics at Texas Tech University. He has specialized in the computational mechanics of fracture, rock, composites and glaciers. In recent years he has organized several outreach activities with K-12 education. These include math enrichment activities at different levels, clubs for middle school girls, service learning coordination, and teacher workshops.

KATHERINE HITCHCOX

Ms. Hitchcox is an engineering graduate of the University of Virginia. She has worked as a consultant on several educational outreach projects for the University of Tennessee. She has designed numerous science and engineering activities for middle schools and presented a series of inquiry based classes at different grade levels. She has presented teacher workshops and organized girls-only math clubs.