AC 2008-2070: INTRODUCING ENGINEERING THROUGH CANDY

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Introducing Engineering through Candy

Abstract

Food engineering is a multidisciplinary field that deals with different aspects of food production and processing. Students' familiarity with candy provides an excellent way to introduce middle school students to the sweeter aspects of engineering. A module that covered several mathematics concepts was developed around candy engineering.

The National Science Foundation Grades K-12 Fellowship offered at Drexel University College of Engineering paired a graduate student with a middle school teacher from the School District of Philadelphia. The team developed engineering-based several modules for inclusion in the middle school curriculum. The schools where the modules are being implemented consist of underrepresented students. In this atmosphere a single module was developed and implemented on mass, volume and density of two different candies. Upon the completion of the lesson activities the students were able to differentiate between mass and volume as well as calculate density.

The design of the module ensured that math skills that the students were having difficulty mastering were covered. The result of ensuring adequate coverage of the math skills in the module resulted in improvements measured on regionally administered benchmark exams. Analysis of student performance showed 19/26 students answered 75% or greater of the question on regional math benchmarks correctly. The improvement of student scores on the benchmark exams can be traced back to the overlap of the module with the math skills covered and their appearance on the benchmark exams.

Introduction

Delicious and inviting, food elicits a positive reaction from students young and old. The Food Network and the A&E specials are testament to the popularity that food has derived. The familiarity that we have with food can be harnessed to exemplify engineering. M&Ms has been used to teach math for many years and many great examples are given online about the distribution of colors in a bag of M&Ms. Instead of using the candy to learn basic statistics, Skittles and M&Ms can be used to expand science and math concepts using engineering as a vehicle for fifth grade students. In order to provide insight into food engineering, a module was developed at Martha Washington Elementary in Philadelphia, PA.

Martha Washington Elementary was one of the sites selected to host a Drexel University GK-12 Fellow. In collaboration with the Fifth and Six grade teachers, a module was designed, after observing the students and their performance on math benchmarks. Two concepts, in particular needed help and the module was built to ensure those math standards were covered in depth. After completion of the module, student's performance on benchmark exams and attitudes in science were investigated. The increase in performance on benchmark exams and increase in the positive attitudes toward engineering.

Background

The module was conducted at Martha Washington Elementary School in the Philadelphia School District. The module was part of a fellowship program through the National Science Foundation for Grades K-12 offered at the Drexel University College of Engineering. The fellowship paired teams of graduate students and middle school teachers in order to developed engineering-based modules for inclusion in the middle school curriculum. The student population of Martha Washington Elementary School primarily consists of students traditionally underrepresented in science, mathematics and engineering. In this atmosphere a module was developed and implemented to teach mass, volume and density of two different candies that focused on providing support to the math curriculum.

The class in which the module was deployed consisted of 30 students. The thirty students by gender broke down to 18 females and 12 males in the class. The Student population demographics at Martha Washington Elementary School are 97% African American, 2% Hispanic and 1% of other ethnicities that were not white. Included in the student population were the special education students who made up 19% of the student population. Only 1% of the student population was considered Limited English Proficiency.

The fifth grade science curriculum is broken into three sections that cover Solar Energy, Variables and Environments. The candy engineering module fits into the Variables section of the Science Curriculum covered in the Pennsylvania Science and Technology standards under the Unifying Theme standard 3.1.7 and Science, Technology and Human Endeavors standard 3.8.7. The focus of the module however was on two Pennsylvania mathematics standards covering Computation and Estimation 2.2.5 and Statistics and Data Analysis 2.6.5.

Strategies

The 5th grade science core curriculum in the School District of Philadelphia is based on three units designed around Pennsylvania educational standards: Solar Energy, Variables and Ecosystems. Each of these units is designed as an inquiry-based science experience, supported by FOSS activity kits (Solar Energy and Variables) and Holt Science and Technology Short Course Materials (Ecosystems). The module "Introducing Engineering through Candy" was designed to be incorporated in the Variables section as a supplement to several activities on density and inquiry. The module covered the same information as the activities and the students were able to use their science books as guides, but instead of measuring mass and volume of penny's the students measured the mass and volume of Skittles and M&Ms. The activities were meant to meet one of the stated strategic objectives of the School District of Philadelphia, which calls for the "development, design and implementation of a core curriculum that is aligned to state standards."

The module was broken down into three lesson activities: Mass & Volume, Density and The Mass Balance. The module spanned a 4 week period and occupied 4 hours per week slotted for science class. A group of four to five students for each activity would receive a small bag of M&Ms and Skittles purchased at a local store and used as received. In order to measure mass and volume a balance and graduated cylinder were used. For the mass balance, students constructed

paper chutes of different designs. The students used science journals to record their work, as shown in figure 2.

The module lesson plan and activities are available online from the Drexel University GK-12 program website at http://gk12.coe.drexel.edu/ and are freely available for download. A synopsis of these lesson plans is provided.

Activity 1: The Mass & Volume of Candy

In this activity, students learn about mass and volume using a balance, graduated cylinder, statistics and graphing to answer the question, "which has more mass/volume an M&M or Skittle?" This activity was used to augment curricular lessons involved in formulating experiments, analyzing data and answering questions. The students by the end became familiar with the units of mass and volume, measuring mass and volume with the appropriate tools, representing statistical data and computing using calculators. To accomplish the students' goal, they were provided a series of writing prompts to answer during the experiment.

Each group of students was given a cup of M&Ms and a cup of Skittles. The class was then polled about which was bigger a Skittle or M&M? The students represented their initial guesses in pie charts and stated their own notions about the candy. The students measured the mass of the M&Ms and the mass of Skittles by pouring the Skittles and then the M&Ms into the balance and measuring the mass. In a similar manner the students can fill the graduated cylinder with M&Ms and record the volume of a handful of M&M. Once the groups collected the data, the students shared their answers with the rest of the class. The mean, median and mode of the results were taken and the students answered the initial question about which candy was bigger.

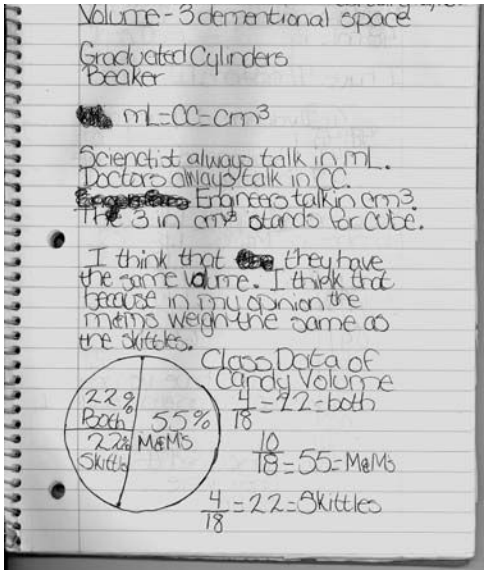

Figure 2: A student's notebook on predicting whether M&Ms or Skittles are bigger.

During the discussion of the experiment, the following question was posed, "the volume we measured is not a true volume of the M&M? Why?" The students should notice that there

were spaces between the candy pieces. The choice of a graduated cylinder to measure the volume of the M&Ms and Skittles does not measure the volume of a single piece of candy. This seemingly critical mistake in the lesson contributed to a discussion in the class on how this difference would affect the outcome and about improving our experiments to measure a single candy piece. The experiment on the volume and density was then redone by using the change in the water level. The students went further to find that when each one of them divided the new volume measured by the initial volume; the students all obtained a value of 0.67. Interestingly sphere's pack with a packing ratio close to the value we obtained. This seemingly offensive oversight provided an excellent discussion and the results differ by a constant value. This makes it possible to follow through the density calculations without losing the principles and perhaps could lead to discussions on crystallography.

Activity 2: Density

Students will learn about density using data that they have previously collected. Density is covered in their science books and this activity supplemented a series of experiments using paper cups to determine density of coins. The goal of this activity was to calculate density and make predictions using mathematical tools. This activity can be used to augment curricular lessons, especially those involved in analyzing data and answering questions. The students by the end should become familiar with the basics of density.

Based on their previous notion of mass and volume the students were asked "which is more dense a Skittle or an M&M?" Without calculating the answer the students' previous notions were polled and the same basic statistics were used to represent their predictions. The students read a section in their science books about Archimedes and his bath; then introduced to the units of density and its definition. The students then relied on their lab notebooks and previous experiments to calculate the density in their science journals.

The question posed was, "would the M&Ms sink or float in water? Would the M&Ms sink or float in Skittles Support your answer?" The students then used Archimedes principle to support their answer. Archimedes principle was first demonstrated by dropping the Skittles and M&Ms into water. In both cases the candy sank and the students wrote down their observations. To demonstrate the second question, a container was filled 1/3 the way up with M&Ms and 1/3 the way up with Skittles. The candy was evenly mixed and the container was sealed. The container was shaken several times, placed on the table and the lid removed. The M&Ms and Skittles separated, and when the students viewed inside the container, the M&Ms should be on top because they are less dense. The students again recorded their observation and saw the Archimedes principle in action. A discussion then ensued about the problem that may arise when a new line of candy is being developed where Skittles and M&Ms could be mixed and placed in the same bag.

Activity 3: The Mass Balance

The mass balance will be used to demonstrate and extend the idea to a liquid flow. The mass balance is not covered in their science books yet this activity supplemented a series of experiments on pendulums. This activity can be used to augment curricular lessons, especially

those involved in analyzing data and answering questions. The students by the end should become familiar with the basics of mass balance.

Students should be familiar with the different types of graphs (line, bar and pie) and converting from fractions to decimals. Also, students should be familiar with averaging, collecting data, mass and volume. The goal is to get the students familiar with mass balances, how it is calculated and how to make predictions using mathematical tools. In order to setup the experiments, a series of paper sheets were taped together to make a chute in different patterns. Then students setup the pipes on a stand. During the experiment, students take a handful of M&Ms which they have counted and drop them into one end of the chute. The students collect the effluent and count them. Some of the M&Ms dropped out of the chute during the experiment; those M&Ms were counted and held separately from the rest of the M&Ms.

The difference between In and Out determined what is happening in the chutes. During the course of the experiment accumulation and disappearance of M&Ms was explained since candy was falling out of the chutes. If we get more candy out than we put in, then we call it accumulation. If we get less out then we put in we call it disappearance. And if the is no loss of candy we say there was no accumulation. In this way the students identified how many pieces of candy fell on the floor and then verified it with the number candy pieces they collected off the floor.

During the discussion, the students asked why it is called a mass balance even though we are counting M&Ms. In response, the students know each M&M and Skittle has a mass, so if it is known how many M&Ms we put in we also know how much mass those M&Ms have. When the M&Ms come out on the other side we count them up and multiply by the mass of one M&M. We could easily call it a number of candy pieces balance, but scientists like to work with masses because it is easier to weigh a lot of M&Ms then to count them all individually; so we call it a mass balance. The concept of the mass balance and design of the chutes to transport M&Ms enables the students to understand how engineering the movement of candy relates to engineering.

Results & Discussion

Student progress

The module enabled the students to learn about mass, volume, density and mass balance. In addition the module provided the students an opportunity to gain experience thinking about science and engineering while they:

- Gained experience with mass, volume, density and buoyancy.
- Made predictions.
- Applied mathematics in the context of science.
- Used statistics to help them solve problems and record and graph data concretely, pictorially, and symbolically to discover relationships.
- Converted data between fractions and decimals as well as learned about units.
- Acquired the vocabulary associated with controlled experimentation.

- Used scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, organizing, and relating.

This module was specifically designed to target two math standards, in addition to fitting into the science curriculum. This emphasized the connection between science and math. However, measuring improvements in science standards covered is difficult since no standardized exam exists. Of the 30 students, 16 received A's, 10 received B's and four received D's. The four that received D's did not complete the assignments asked of them. No correlation was found between the science grades and math benchmarks.

The candy engineering module was one of several modules developed over a year. Throughout the course of the year student benchmark scores improved, correlating well with the introduction of the fellow implementing modules with the students at the end of October, which corresponded to a 15% increase in their math benchmarks. Students performed above average throughout the year; however, the class performance before and after the module improved approximately 6%, corresponding to a 32 more questions being answered correctly out of 540 to total questions for the whole class. The benchmark scores were ~20% higher than the average for district and region of Philadelphia.

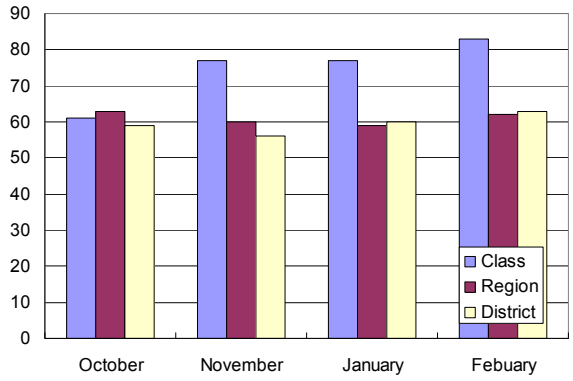

Figure 3: Math benchmark results for the 5th grade class, Philadelphia region and west Philadelphia district.

The increase in the number of questions correctly being answered resulted in an increase in the number of students who scored 75% or higher on their benchmark exams from 14 to 19, which corresponded to a decrease in the number of students scoring below 75% and below 50%. Above, 75% students are considered advanced proficient and below 50% students are considered below proficient.

The math benchmark exam is broken down into a series of standards, the result of which is shown in Table 1. Breaking down the math benchmark exams before and after by the standards addressed during the exam, the standards that were correlated to the module showed significant improvement while those that were not covered did not show any improvement and in fact slightly decreased. The six percent increase in the benchmarks can be attributed to two of the four standards covered on the math benchmarks. On Pennsylvania math standard on Computation and Estimation, 2.2.5, an increase in the number of questions answered correctly on

the math benchmark of 18% was observed. This attributed to the student's answering as a class about 34 additional questions correctly. A 10% increase in questions answered correctly on the Pennsylvania math standard on Statistics and Data Analysis 2.6.5 was observed. This corresponded to an additional 8 questions answered correctly. The 42 additional questions answered correctly attributed to a 7.7% increase in the overall student performance on the math benchmarks.

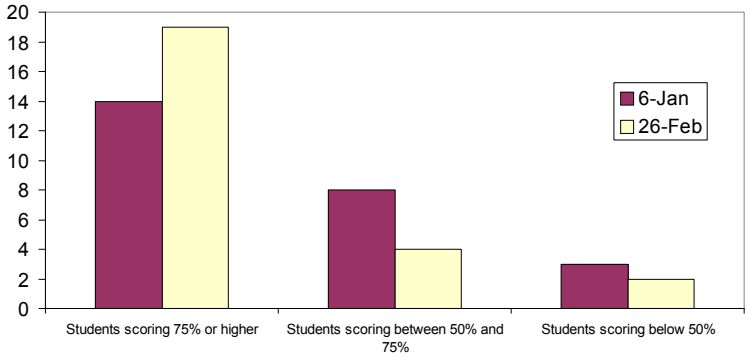

Figure 4: Student performance on the math benchmark exams before and after module implementation.

On the other hand, the two standards not covered did not show any increase during February's math benchmark exam. The PA math standard 2.1.5 and 2.9.5 dealing with Number Theory and Geometry were not addressed during the module, though they were taught during the regular math class over the same time period. As a result the small decreases in performance led to a 1% overall decrease in student performance on the benchmarks or 8 questions less being answered correctly. In total this led to 6.7% increase, which is approximately equal to the 6% overall performance seen in figure 3. The small improvement in the student performance on the math benchmark exams comes from the improvement on two standards addressed during the module. In light of the connection between the student improvement on their math benchmark exams and the module, care should be taken in extrapolating these results.

Standard	The standard correlated to math benchmark or uncorrelated	% of Questions answered correctly BEFORE module	# Questions on standard BEFORE module	% of Questions answered correctly AFTER module	# Questions on standard AFTER module
2.1.5	Uncorrelated	68	607	66	180
2.9.5	Uncorrelated	68	288	65	60
2.2.5	Correlated	70	257	88	210
2.6.5	Correlated	69	280	79	90

Table 1: Percentage of questions correctly answered separated by standard

The module covered many topics both in math and science and spanned several weeks, yet it was not the only tool being used to teach the students math and science. Instead the module should be looked at as a method that helped reinforce concepts and ideas that were covered in class. Visualization of the how the GK-12 module overlaps with math benchmarks can be seen in

Figure 5. The teacher is covering many topics that will be on the benchmark exams. The math lessons cover the benchmark exams while the module was able to cover two of the four standards on the exam. The teacher in addition to covering all the standards on the benchmark exam covered topics relating to Algebra and Functions under standard 2.8.5. While the candy module also covered Pennsylvania math standard 2.9.5 on Probability and Predictions both standards were not covered on the benchmark exam in February. The additional aid provided by the candy engineering module may have attributed to the increase in the student performance on the math benchmarks.

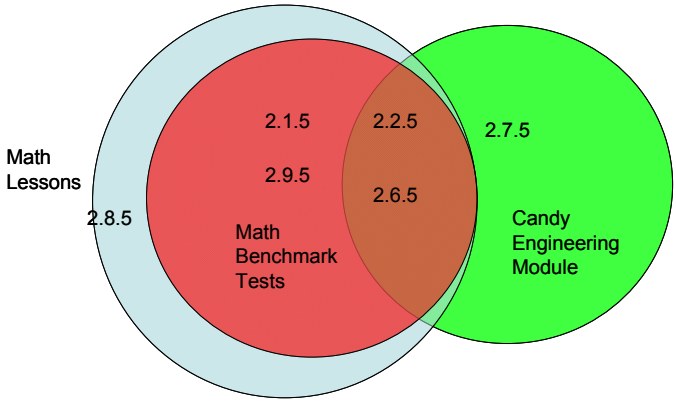

Figure 5: A diagram of how the candy engineering module and math lessons overlapped with the math benchmarks

In addition to the increase in performance that the students demonstrated, the experience that the students gained was also looked at positively in terms of their attitude toward engineering. The students were provided a survey at the outset of the module about their attitudes toward engineering and science. The survey consisted of 26 questions of yes, no and unsure. From this survey the student's responses before and after were compared. 50% of the students responded positively when asked if science is fun. The ratio of positive responses stayed the same before and after.

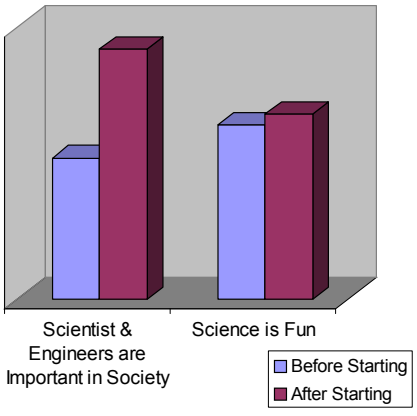

Figure 6: Attitudes towards the importance of engineering and science before and after the module.

However, when asked if science and engineering are important to society student positive attitudes changed by 40% from 50% to 90%. Of the students who scored less than 75% six out of the seven answered that scientist and engineers are important in society, while four out of seven answered that science is fun which showed no significant deviation from the rest of the class. The results of student attitudes towards engineering and science before and after the module can be seen in Figure 6.

Teacher Attitude towards Module

The module was developed and implemented with the teachers from Martha Washington in the hopes that they would be able to continue to use and expand on the module for use in their classrooms. A survey that the teachers completed after the module provided feedback on what the teachers liked and disliked. Of interest was that, "the lessons demonstrated various ways, in which meaningful math and language arts was incorporated into the science lessons." While another teacher said that, "the higher order thinking and methods/experiments used to connect math and science are strategies I will continue to use." The teachers stated that they felt more confident with the math and science concepts involved in the lesson and thought they could perform the modules on their own.

Conclusion

The students' familiarity with candy was used to introduce middle school students to a basic principle of engineering. The module was conducted at Martha Washington Elementary School in the Philadelphia School District had a student population of Martha Washington Elementary School primarily consists of students traditionally underrepresented in science, mathematics and engineering. A module was developed and implemented to teach mass, volume and density of two different candies.

In this case study of implementing engineering modules, the students were able to differentiate between mass and volume, calculate density, and had learned two important engineering concepts. A secondary benefit of this module was the improvement in math skills. Upon analysis of the students' performance, 19 of 26 students scored advanced proficient on the regional math benchmarks. The class answered 83% of the questions correctly on the same benchmark, an improvement of 6% from the previous benchmark. These improvements can be attributed to the overlap of the science module with the math curriculum while the candy gave the students a new perspective on engineering.

Future Work

The continued success of this module will be in its implementation as part of the fifth grade curriculum at Martha Washington Elementary. In order to facilitate the modules incorporation a one year follow up is being planed, in which the teacher will give the lesson in the presence of the fellow to insure fidelity of the modules delivery. Using the same indicators for success it is expected that similar improvements could be achieved.

Acknowledgments

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