AC 2012-3027: IOWA STATE UNIVERSITY SYMBI GK-12 PROGRAM: A CASE STUDY OF THE RESIDENT ENGINEER'S EFFECTS ON EIGHTH GRADERS' ATTITUDES TOWARD SCIENCE AND ENGINEERING

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IOWA STATE UNIVERSITY SYMBI GK12 PROGRAM: A CASE STUDY OF THE RESIDENT ENGINEER'S EFFECTS ON 8TH GRADERS ATTITUDES TOWARD SCIENCE AND ENGINEERING

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ABSTRACT

Symbi, Iowa's NSF GK12 program, is a partnership between Iowa State University and the Des Moines public school system in an effort to develop innovative and engaging STEM (Science, Technology, Engineering and Math) activities for middle school students. STEM graduate students are selected to serve as resident scientists or engineers and spend one full day each week throughout the academic school year in a middle school science classroom. These GK12 Fellows engage the students by providing inquiry-based learning experiences and authentic demonstrations, which bring relevance by relating the science curriculum to real world challenges. In addition, the Fellows serve as role models for STEM based occupations and encourage the students to develop the skill-sets they will need to be competitive in the 21st century global economy. Each Fellow's research background provides a unique venue for enhancing the classroom curricula. Here we present a case study showcasing the activities and interactions of Symbi GK12 Fellows in the classroom with implications for other partnerships between graduate students and middle schools. In this case study, the primary research focus of the author, a GK12 Fellow, is on materials science and engineering, a field completely absent from middle school curricula. By providing hands on demonstrations and reliable scientific expertise, 8th grade students showed a significant increase in not only academic understanding but also in attitudes toward science and engineering related fields. These findings were supported through pre- and post-survey instruments, and student testimonies. These results suggest that middle school students benefit from the involvement of the resident engineer in the classroom.

INTRODUCTION

On the 27th of April 2009 at the National Academy of Sciences, President Obama said, "*I want to persuade you to spend time in the classroom, talking and showing young people what it is that your work can mean, and what it means to you […] to thinking about new creative ways to engage young people in science and engineering*." These words came in the wake of growing concern for the lack of students pursuing degrees and careers in STEM (Science, Technology, Engineering and Math) related fields. Currently, the pool of engineers in the United States is undersized to meet the needs of our society and economy [1]. If current trends do not change, the demand for engineers will surpass the supply of engineers in the US [2].

A startling number of students in the US are failing to pass science benchmark standards at a proficient level. According to the National Center for Educational Statistics, fewer than 1 out of 3 students perform at or above the proficiency level in 8th grade science [3]. Students from low income and underrepresented minority families scored significantly lower on the national report card [4]. Additionally, the public school students performed well below private and Catholic schools, especially in the inner city public school setting [4]. These scores demonstrate that the K12 public science education in the United States is substandard.

In an effort to address student STEM literacy and preparation for STEM careers, Iowa State University has partnered with the Des Moines Public Schools to foster students' interest in science and engineering by incorporating STEM Ph.D. candidates as resident scientists/engineers in middle school classrooms. This partnership is funded by the National Science Foundation (NSF) through the Graduate Stem Fellows in K-12 Education Program (GK-12). NSF funds several GK-12 programs at national universities. Each university has specific and unique goals for their program. A goal of Iowa State University's GK-12 program, *Symbi,* is to increase K12 students' scientific literacy: that is, to increase student understanding of the relevance of STEM to real world challenges and to help them be more aware of STEM careers. The program name *Symbi* was chosen for the symbiotic relationship between the fellows and the middle school students.

The lead author of this article is a Symbi GK12 fellow and "resident engineer" who is majoring in materials science and engineering and conducting research on polymers. The resident engineer was paired with a middle school science teacher in the Des Moines Public School District, and spent one full day each week, for one academic year, in the science classroom. The resident engineer was able to provide a unique classroom experience by periodically introducing the students to aspects of his own research, including the use of biopolymers in material self-healing applications. Several activities were designed to provide students with the opportunity to learn about the field of polymer science. These activities were related to the science topics covered in the curriculum and provided relevance to real world issues and challenges. This study focuses on the impact this fellow has had as a resident engineer on the students in his classroom.

RESEARCH QUESTIONS

In this case study, researchers were interested in the effects of a resident engineer on eighth grade students' science content knowledge and attitudes toward science and engineering. Specifically, this study asks whether the resident engineer improves the interest of students in science and engineering such that significant improvement in the scientific knowledge of the students can be detected. The current study was guided by two basic research questions:

1. Do the classroom activities, demonstrations, and experiments provided by the resident engineer positively affect the attitudes of students toward science and engineering, specifically in fields relatively unexplored by 8th grade science classrooms such as polymers?
2. Are there significant changes in student knowledge about polymers after exposure to materials science demonstrations?

RESEARCH DESIGN

This case study focuses on a defined classroom situation in which a series of demonstrations involving polymers, showcasing polymer engineering concepts, were conducted by the resident engineer.

Four different demonstrations were conducted with the objective of enhancing the energy unit of the science curriculum. The demonstrations used in the classroom were as follows:

1. **Thin Film BioPolymer** – This activity involved the polymerization of a thin film biopolymer. The film cast in this polymerization process was made from a mixture of water, gelatin, and glycerol. The demonstration utilized laboratory equipment such as beakers, hot plate, flasks, and scales to show how polymers are made in the laboratory. During the demonstration, a discussion on the nature of polymers, how they are made, where they are found, and how often they are used in daily life was utilized to expand students' knowledge of polymers. The resident engineer connected the thin films to the students' life by discussing applications involving smart phones and electronic thin film display covers.
2. **Nylon 6,10** – A second polymerization process was demonstrated for students to experience a fraction of the many methods for making polymers. In this demonstration a solution of sebacoyl chloride and heptane was added to a solution of hexamethylenediamine and water. At the interface of the two insoluble solutions, a thin film of nylon forms and a fiber is pulled for students to see. A discussion about the origin of nylon, the uses for nylon, and the processing of nylon was done.
3. **Exothermic Reaction** – This activity demonstrates the conversion of potential energy stored in chemical bonds to thermal energy. For this experiment, hydrogen peroxide was added to yeast and mixed for 10-15 seconds. During this time, the temperature of mixture raises and a discussion on the importance of understanding your material reactions, especially in polymerization, is crucial for safety as well as an excellent way to explain the application to the energy unit in the science curriculum.
4. **Endothermic Reaction** – Similar to the exothermic reaction, this activity used a mixture of vinegar and baking soda. As the temperature decreases, the lead author discussed with the students the effects of endothermic reactions and again references the need for understanding a reaction and applying it to the science curriculum.

In order to evaluate the effect of the resident engineer in the classroom, pre- and post-survey instruments were implemented to assess 8^{th} grade student attitudes to science and engineering as well as student understanding of concepts relating to materials science engineering (described below).

CLASSROOM DEMOGRAPHICS

The resident engineer was paired with the eighth grade science class at Meredith middle school, Des Moines, IA. The middle school has a total of 607 students, of which 162 were in the eighth grade science classroom that interacted with the resident engineer. The student population of Meredith middle school is 58% underrepresented minority families and 69.4% of all students qualify for free or reduced lunches. These demographics are comparable to the national average of 56% underrepresented minority families from the 2009-2010 National Center for Education Statistics (NCES) data [5].

RESULTS

Before the classroom demonstrations listed above, the students were given a pretest survey to gauge their understanding and interests in polymers. After the demonstrations were conducted, the students were given the same survey in order to understand the effects of the polymer demonstrations. Questions 1-3 were answered on a scale of 1 to 5 where 1=No Interest and 5=Very Interested. Questions 4-9 were true or false questions. Table 1 shows the data for questions 1-3 and Table 2 shows the results for the true or false questions. These questions were as follows:

1. What is your interest in science?
2. What is your interest in materials?
3. What is your interest in polymers?
4. Are plastics a type of polymer?
5. Are polymers made from petroleum?
6. Are plastics made from vegetable oils?
7. Are all man made polymers bad for the environment?
8. Are some polymers safe to eat?
9. Do I use polymers all the time?

Table 1. Class demonstration survey – Questions on students' interest

	Pre-Class Survey		Post-Class Survey		Single Tailed Paired *t*-test
	Mean	Std. Dev.	Mean	Std. Dev.	Significance
Question 1	3.40	0.98	4.06	0.82	3.02 E-17
Question 2	3.02	1.18	3.68	1.00	4.64 E-17
Question 3	1.80	0.95	3.55	0.99	1.73 E-40

Table 2. Class demonstration survey – True or False Questions

	Pre-Class Survey (% Correct)	Post-Class Survey (% Correct)	Single Tailed Paired *t*-test
Question 4	70.8	94.9	3.26 E-8
Question 5	50.4	60.6	4.00 E-02
Question 6	34.3	62.8	9.06 E-8
Question 7	72.3	93.4	3.56 E-7
Question 8	36.5	92.0	1.25 E-22
Question 9	65.0	91.2	2.46 E-8

It is worth noting that the resident engineer had been in the 8^{th} grade class for almost a full semester before the classroom demonstrations were performed. Because of this, the students were already familiar with, and comfortable with, the resident engineer in the classroom.

In addition to the survey questions and statistics, a tangible difference in the students and their interest in science was observed by the resident engineer. Upon his arriving, many students are excited to see him. They often wanted to see what demos, labs, or experiments were brought and what the class was going to be doing. Students made comments such as, "Hey science dude, you make science class cool" or "what awesome science stuff are we doing today?" and "I wish you could come every day." In fact, on the day of the polymer demonstrations, few students had any idea that polymers were in many of their foods, let alone that they had eaten a polymer. Once students found out that polymers were in food and that some polymer engineers work with making candies like gummy animals, they were quite interested to learn more about these kinds of jobs.

DISCUSSION

In middle school the focus of STEM is solely on science and mathematics [6]. However, the study of engineering is an excellent way to incorporate science, mathematical and technological principles into examples of real world phenomena. [7]. Engineering concepts provide an effective way for educators to interweave subjects, especially in the middle grades, and to help their students identify and formulate problems, design solutions, test and improve designs, and communicate results to others. By introducing engineering concepts at an early age, especially through hands-on activities, students can improve their understanding of the subject matter and its relevance to their lives [7,8].

The absence of engineering concepts in the middle school math and science curricula not only stunts the potential for higher learning of students, but it is also reinforces a stereotype that science and engineering are tedious and uninteresting fields full of difficult concepts and far removed from the average person. Many middle school students are uninterested in science because they do not see the relevance to their life experiences and a perception of their inability in science [9]. In fact, most students' attitudes toward science decreases throughout middle school and high school and these attitudes are strongly linked to their best friends' attitudes toward science [10]. However, the influence of teacher encouragement has shown to have a positive effect on students [11]. Furthermore, introducing engineering concepts in middle school increases student interest especially in students who generally do not become engaged in the science classroom [8,12].

The data from the classroom survey shows these students' opinions align with the national pattern. The data also supports the observation of the resident engineer that many students do not know what polymers are. The true and false questions from the survey show few students know what polymers are. Question 3 points out students are not interested in polymers and this lack of interest is most likely from a lack of knowledge about polymers. When the students were asked to articulate what a polymer was, very few could give a cohesive answer about polymer understanding. Of all the questions on the survey, only one question, number 5, did not indicate a significant change in student understanding. There is no surprise this question showed insignificant change considering the question was designed to gauge the students' initial understanding of polymers and that the demonstration did not involve discussion of petroleum based polymers. However, all other questions showed a significant increase in understanding of polymers. Students were able to better answer basic questions about polymers as well as expressing an increased interest in polymers.

Despite polymers being vital to our current society, it is not surprising few school curriculums provide an opportunity for the students to explore the nature of polymers. This case study is another example of presenting polymers to students through an interactive environment where they can freely explore, question, and investigate a few aspects of polymers. After the class was finished, several students remained after every demonstration to ask more questions and get more tangible experience with the materials.

Additionally, the classroom profited from a scientist in the classroom who can connect real world application to the classroom curriculum. Primarily, this benefit was seen in the increased understanding students held about science and engineering as solutions to real world problems. When the resident engineer first entered the class, the students would often respond with, “who cares,” after the resident engineer would talk about interesting science phenomenon. However, when the classroom began to learn how the materials they were learning about had real world application such as polymers in food, clothing, and airplane parts, students became engaged. Students were even asking where they will see science they learned in their everyday life before the resident engineer could offer applications for them. For example, throughout the classroom demonstrations, students became more comfortable and interested in asking questions about polymers. In fact, few had any idea that they had ever worn a polymer (nylon, polyester, spandex, or rayon). Furthermore, the resident scientist provided a tangible figure who was working to solve actual problems involving polymers. By offering concrete examples of careers in science and engineering, students began to see themselves more in a scientific role in their future careers.

These results are supported by the Symbi first-year cohort student attitudes data collected and analyzed by Iowa State University’s Research Institute for Studies in Education (RISE) [13], which showed significant change in 241 eighth grade students’ perceptions of science after involvement in the Symbi GK-12 program. For instance, students showed an increased interest in both problem-solving and engineering concepts. Increased interest in problem-solving was complimented by decreased interest in obtaining answers from the teacher. These results showed that students were beginning to develop critical thinking skills, and were more interested in solving their own problems by taking ownership of the problem instead of relying on a teacher to fall back on for the quick answer.

CONCLUSIONS

The results of this study show that 1.) Introducing engineering concepts in middle school increases student interest especially in students who generally do not become engaged in the science classroom, 2.) Despite polymers being vital to our current society, few school curriculums provide an opportunity for the students to explore the nature of polymers, and therefore students are not interested in them, 3.) The classroom profited from a scientist in the classroom who can connect real world applications to the classroom curriculum by stepping in as a mentor scientist/engineer.

Introducing middle school students to engineering concepts is beneficial to their cognitive development by requiring them to learn several disciplines simultaneously—thus improving not only their science skills but also their mathematics, reasoning, and communication skills. Despite the fact that the public school system has placed a focus on STEM curriculum, few classrooms offer a program that actually advances engineering for students. Often this comes from teachers who lack the ability to comfortably introduce engineering topics to class. However, when students are introduced to new topics in which they obtain hands-on experiences in science through an engineering viewpoint, students’ interests significantly increase. From the survey alone, simply introducing the students to the hands on demonstration increased their interest in science as a whole from 3.40 to 4.06 on a scale of 1 to 5—a statistically significant change.

Often, students are not interested in a topic for the sheer reason that they don’t know anything about it. This is quite evident by the change in interest of polymers before and after the classroom demonstrations. The students’ interests in polymers went from 1.80 to 3.55 on a scale of 1 to 5. From the resident engineer’s perspective, students asked more questions and showed more interest after an introduction to polymers concepts. Students asked about different polymers in food, why certain polymers respond differently to external stimulus, and how polymers break. By providing students relevancy for why they are learning the information in their curriculum, students can begin to see themselves as potential future engineers. Once the students found out about polymers in food, several students were excited about the idea of a job studying the properties of candy. The resident engineer discussed possible applications for biopolymer thin films such as coatings for smart phones and electronics which immediately piqued the interests of several students. The class was even interested in the applications for nylon. The students were shocked at the wide applications for nylon such as fishing line, clothing, drum sticks, parachutes, and a wide variety more. Scientific learning is vastly enhanced once a personal interest is taken in a topic because additional investment is made by the individual to better understand the material.

Past research has shown it is not enough to just get students to learn the material to encourage students to pursue science and engineering careers. Students drop out of their respective science and engineering fields despite having the ability to handle the material. Often attrition happens because students don't see themselves aligning with engineering. However, by fostering the interest in science and engineering, and by providing a figure that represents science and engineering, students begin to see themselves aligning with these fields more closely. In fact, students that are influenced and encouraged by a mentor early are three times more likely to pursue STEM careers [14].

By offering eighth grade students the opportunity to work with a resident engineer, the class is exposed to a mentor who provides design based learning from an engineering perspective. Students get a better appreciation for why science is important in everyday life by interacting with a scientist/engineer and that engineer's presence makes the profession of engineering more tangible. They benefit from experiencing materials such as polymers thereby increasing their interest in new topics they had not heard of before. The results of the surveys show that students experience significant benefit from their resident engineer interactions both in attitude toward science and their understanding of new material, thereby hopefully causing them to become more interested in following STEM careers in their future.

LIMITATIONS

This case study was limited to a single classroom interaction. The scalability and sustainability of a program such as this is always in question. However, one goal of the Symbi program is to assimilate these lessons in a database and disseminate the materials for others to use. The resident engineer is one of several graduate students in the Symbi program. In order to expand the model to an evidentiary basis, the program could look at rotating each resident engineer through different classrooms and collect data on each interaction to observe the effects on multiple classrooms and age groups. Furthermore, the program should look into providing teachers materials to facilitate the demonstrations on their own and evaluate how students respond to material with and without the resident engineer.

It is well-known that teacher knowledge influences student learning. While it might not be feasible to have a resident engineer in every classroom for the long term future, utilizing the materials developed by the resident can provide a foundation for teachers to draw from when looking to introduce engineering concepts in to their classroom. Although the classroom would no longer benefit from the resident scientist as a mentor to the classroom for which students obtain a better appreciation for the profession, it is the authors' feeling that when a teacher is confident in offering the engineering concepts to the classroom, the classroom as a whole can gain substantial academic improvements and individual interest in the classroom. The resident engineer's work provides the support for the teacher to confidently present the material to the classroom in a way that emphasizes engineering concepts.

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