AC 2012-3772: MEASURING THE IMPACT OF AN ELEMENTARY SCHOOL OUTREACH PROGRAM ON STUDENTS' ATTITUDES TOWARD MATHEMATICS AND SCIENCE

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Measuring the Impact of an Elementary Engineering Outreach Program on Students' Attitudes Toward Mathematics and Science

Abstract

It is well known and documented that students in the United States are performing poorly in mathematics and science when compared with students from other countries. Yet, the advancement of our technology rich society requires that students develop advanced skills in these subjects by the conclusion of their formal education. Students' attitudes with respect to mathematics and science are known to be developed at a young age and become entrenched by middle school. In an effort to encourage young students to eventually pursue careers in science, technology, engineering, and mathematics, the Colorado School of Mines has developed the Bechtel K-5 Educational Excellence Initiative. This engineering outreach program is being implemented in five minority elementary schools located throughout the Denver area, each school including grades kindergarten through fifth. One measure of impact of this program is an attitudes survey in mathematics and science. This article presents a study that seeks to statistically examine students' attitudes toward mathematics and science at a very young age by comparing the attitudes of elementary students who have participated in the Bechtel K-5 Educational Excellence Initiative for one year versus students who have not, but are in the same school district. As a result of this study, there is statistical evidence to support that there is a higher proportion of positive attitudes toward science for students who have spent a year in the engineering outreach program when compared with students who have not been in the program. Interestingly, there is not statistical evidence to show that the proportion of positive attitudes toward mathematics is different for students who have been in the program when compared with students who have not been in the program.

Introduction

It has been known for years that students in the United States are performing poorly in mathematics and science when compared to students from other countries. With regard to science, a mere one third of all American students are considered to be proficient within their current grade level and less than two percent are considered to be advanced[11]. The United States is trailing other countries in both mathematics and science based on standardized international test results[8]. With respect to science, the United States falls behind eight other countries when comparing students' performances on the Trends in International Mathematics and Science Study at the fourth grade level and behind five other countries when comparing students' performances at the eighth grade level. In mathematics, the United States falls behind four other countries at the fourth grade level and nine other countries at the eighth grade level on this same test[8]. Having a poor background in mathematics and science has additionally been identified as a factor that contributes to the 40% dropout rate of American students who enter college as engineering majors but fail to complete these degrees[9]. Furthermore, universities in the United States are awarding an increasing number of engineering degrees to foreign students. In 2005, approximately 60% of engineering doctoral degrees and 50% of mathematics and computer science doctoral degrees were awarded to foreign students[2]. Engineering jobs in the U.S. have been the most difficult positions to fill for more than two sequential years (2008 and 2009), and

yet careers in engineering are projected to grow by 11% over the 2008-2018 decade[3,10]. In order to fill engineering careers with competent individuals from the U.S., there is a need to improve the educational system at the elementary, middle, and high school levels, and there is a need to include engineering as an area that is addressed in our educational system.

The idea that engineering and technology should be taught in pre-college schools is somewhat new. According to recent research, most science, technology, engineering, and mathematics (STEM) programs in the United States focus solely on mathematics and science, and leave engineering and technology out[11]. One exception can be found in the state of Massachusetts. This state has integrated engineering and technology into the curriculum, and its students are out performing their peers from the other states on international science and mathematics tests[11]. Researchers have argued that creating an educational environment where students are learning how to apply science and mathematics through the use of engineering and technology is likely to yield a deeper knowledge, understanding, and appreciation of these subjects in students. Researchers have further argued that engineering education should begin in elementary school in order to positively influence students' beliefs early in their education concerning engineering ideas, the design process, and the importance of teamwork[6]. Reformers have tried and, thus far, have failed to significantly influence students' beliefs concerning engineering when the intervention occurs at a secondary level[6]. Secondary education may be too late to significantly influence the subjects that students' value. It is now time to examine the impact of such programs when these programs are implemented at a younger level.

This paper describes an engineering outreach program that is being implemented at an elementary level between the Colorado School of Mines and elementary schools in Adams County District 50. Our program has been developed based on best practices from other successful engineering outreach programs for pre-college schools, such as the outreach program at the University of Colorado at Boulder that was initiated in the fall of 1999[1]. One attribute of a successful outreach program is hosting summer workshops for teachers that are centered on pre-engineering concepts through the use of hands-on experiments and demonstrations that provide teachers with applicable curriculum and lessons[7]. Using this attribute, our outreach program provides a two-week summer workshop for participating elementary school teachers that addresses elementary mathematics and science through its applications to engineering concepts. Another attribute of a successful outreach program is pairing graduate students at universities with pre-college schools, where graduate students become an active and real life role model in the classroom to support the instruction of engineering[1]. Modeling off of this aspect, graduate students in our program provide weekly classroom support to elementary teachers throughout the academic year, by designing and teaching creative lessons that incorporate science, technology, engineering, and mathematics[5]. Additional details are provided in the methods section regarding the summer workshop and responsibilities of the graduate students in the elementary classrooms.

The research questions addressed here are:

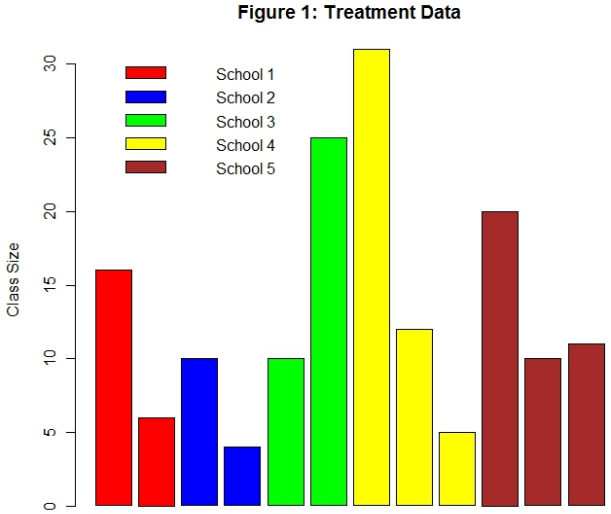
i. Do students who participate in the program have different attitudes toward science and mathematics than students who have not participated in the program?
ii. If there is a difference in attitudes between students who have participated in the program versus students who have not, is there statistical evidence to indicate that

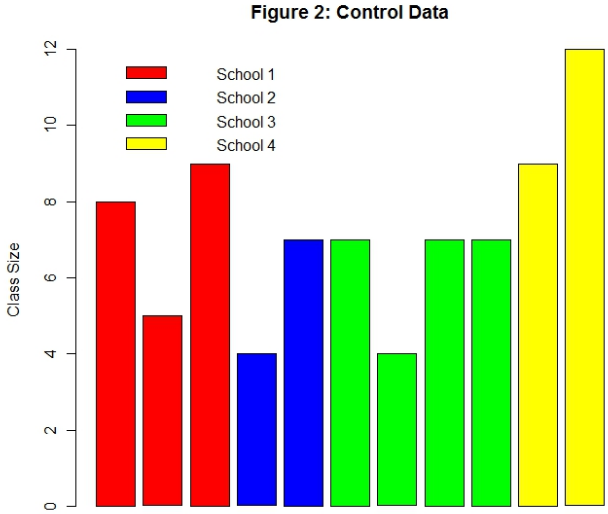
students who participate in the program have a more positive attitude toward science and mathematics than students who have not participated in the program?

Methods

Subjects. There were two sets of categorical data used in this investigation. The data was drawn from an attitudes survey administered in May 2011 to elementary students, kindergarten through fifth grade, in Adams County District 50 in Denver, Colorado. The first set of data was from elementary students who participated in the Bechtel K-5 Educational Excellence Initiative, which will be referred to as the treatment group. The second set of data was from elementary students who have not participated in the Bechtel K-5 Educational Excellence Initiative, which will be referred to as the control group. Both the treatment and control consist of students from the same school district.

Schools. As is reflected in Figure 1 and Figure 2 respectively, there were five schools and 12 classrooms in the treatment group, and there were four schools and 11 classrooms in the control group. All elementary schools are located in Adams County District 50. The total sample size for the treatment group was 160 students, while the total sample size for the control group was 79 students.





Instrument. The attitudes survey is a 26-question survey that was developed in-house, and prior articles provide evidence to support its validity and reliability for use with the kindergarten through fifth grade population[4]. The survey is available in two languages, English and Spanish, and is read aloud to the participating students in both languages. Additionally, young students can respond to this instrument because the response categories require that they circle either a smiley or frowny face to designate a “yes” or “no” response, respectively. The questions on this survey are related to students' interests in science and mathematics, students' beliefs about their abilities in science and mathematics, how important students view science and mathematics, and their perception of their parents’ beliefs on students' success in science and mathematics. If a

student failed to answer a specific question, that student was eliminated from the analysis for that question. This instrument was completed at the end of the school year, after participating students and their teachers had been in this program for a full year. Data was only used from students whose legal guardian's provided written consent to participate in this investigation.

Analysis. Multiple hypothesis tests to compare proportions of two populations were used to compare the treatment and control responses. A requirement for these tests is that the data be independent. Before performing the desired tests for given questions from the survey, the chi-square test for independence was used to examine independence between the classes in the treatment and control. If the classes were found to be independent from each other, they were combined to form one sample of independent data for each group, treatment and control. This process was completed on all of the questions from the survey, and classes that were not independent from the others were removed. Additionally, when the assumptions of the test could not be made, only descriptive statistics were examined.

Previous research used an exploratory factor analysis on this survey and resulted in the identification of two factors, a desirability and a capability factor[4]. Based on these two factors, questions from the 26-question attitudes survey were divided into their corresponding factors for analysis. Table 1 summarizes the questions from the attitudes survey for the desirability and capability factors, and these are the questions that are analyzed here.

Table 1: Questions for Analysis

Factor 1: Desirability	Factor 2: Capability
1. Do you like math?	1. Are you good at math?
2. Do you like science?	2. Are you good at science?
3. Do you want to learn math?	3. Do your parents think you can do well in math?
4. Do you want to learn science?	4. Do your parents think you can do well in science?
5. Do your parents want you to do well in math?	5. Is science easy for you to learn?
6. Do your parents want you to do well in science?	6. Is math homework easy for you?
7. Do your parents expect you to do well in math?	7. Is math difficult for you?
8. Do your parents expect you to do well in science?	8. Is science difficult for you?
9. Is math important for you to learn?	9. Do you have trouble solving math problems?
10. Is science important for you to learn?	10. Do your parents think that math is too hard for you?
11. Is math important to know?	11. Do your parents think that science is too hard for you?
12. Is science important to know?	
13. Do adults use math a lot?	
14. Will you use math when you are an adult?	
15. Will you use science when you are an adult?	

Intervention. The Bechtel K-5 Educational Excellence Initiative supports the development of elementary teachers' knowledge of mathematics and science through a two-week, hands-on, summer workshop and a classroom follow-up completed by graduate students that occurs throughout the academic year. The summer workshop focuses on specific engineering topics

each year and for the summer 2011 workshop, the focus was on renewable energy. Faculty and graduate students from our university in addition to engineers from companies and a national laboratory presented sessions on renewable energy topics. Graduate students are paired with teachers during these sessions to collaborate on experiments and projects that deepen the understanding of both the graduate students and elementary teachers in mathematics and science. Lesson plans are provided for each of the presentations during the workshop that teachers can readily use in the elementary classroom. The summer workshop also allows elementary teachers and graduate students to create rapport with one another as they will be supporting one another throughout the academic year and will benefit from having a working relationship formed before the academic year begins. Approximately half of the summer workshop is structured for instruction of STEM and renewable energy topics, while the remaining time is devoted to hands-on experiments with scientific equipment.

Specific topics and lessons that were taught in the 2011 summer workshop include the following: circuits and currents, hydrates and molecular simulation, conductors and insulators, electricity and magnetism, forms and sources of energy, energy storage and batteries, history of energy, optics, photovoltaics, solar and thermal energy, hydrogen and fuel cells, and energy-efficient buildings. Teachers and graduate students can than use these lesson ideas in their classroom. Lastly, in an effort to enhance elementary teachers' experience with renewable energy and real world laboratories, graduate students and elementary teachers participated in a guided tour of the National Renewable Energy Laboratory located in Golden, Colorado.

Throughout the academic year, graduate students support their elementary teachers 15-20 hours a week. The responsibilities of graduate students include teaching science, technology, engineering, and mathematics to elementary students in an engaging manner such as using demonstrations or hands-on experiments, providing the teacher and students with scientific materials and equipment, and creating after school clubs for interested students to investigate deeper into STEM related topics. Graduate students provide instruction side-by-side with their teacher in an effort to support the current curriculum and provide the teacher with confidence in teaching subjects for which they have minimal training (mathematics and science). The end goal is to provide these teachers with lesson plans, scientific materials, and a deeper understanding of STEM related topics that will enable them to independently teach these subjects in future years in an effective and efficient manner. Graduate students use lessons from the summer workshop in addition to creating new lessons that comply with district and state standards. All graduate students are required to post lesson plans on their websites, and examples of lesson plans from current fellows in the program can be found on the Bechtel K-5 Educational Excellence Initiative webpage[5].

Results

Desirability Factor. It should be noted that all fifteen questions for the desirability factor in Table 1 are positively worded. As a result, the “yes” responses indicate a positive attitude toward mathematics or science. When analyzing the fifteen questions related to the desirability factor, the proportion of positive responses to the questions for the desirability factor ranged between 92-99% for every question in the control except question 13. Since the proportions were close to 100%, the assumption of the hypothesis test to compare two populations was not met in the

control and could not be used. Given this, only descriptive statistics are presented here concerning the desirability factor. For question 13, the hypothesis test revealed that there was no statistical evidence to indicate that the proportion of "yes" responses in the control was significantly different than the treatment.

Figure 3: Proportions for Desirability Factor

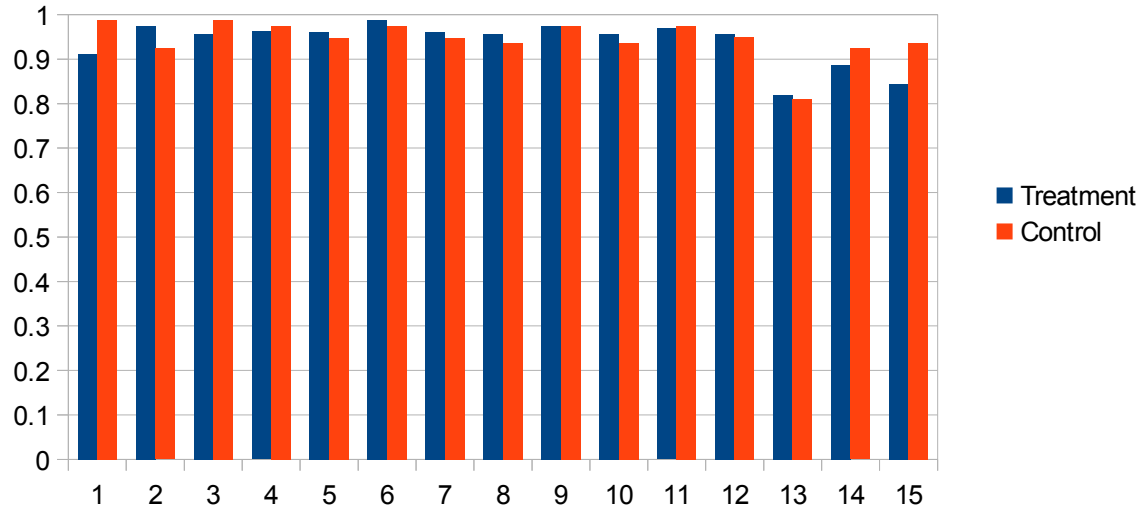
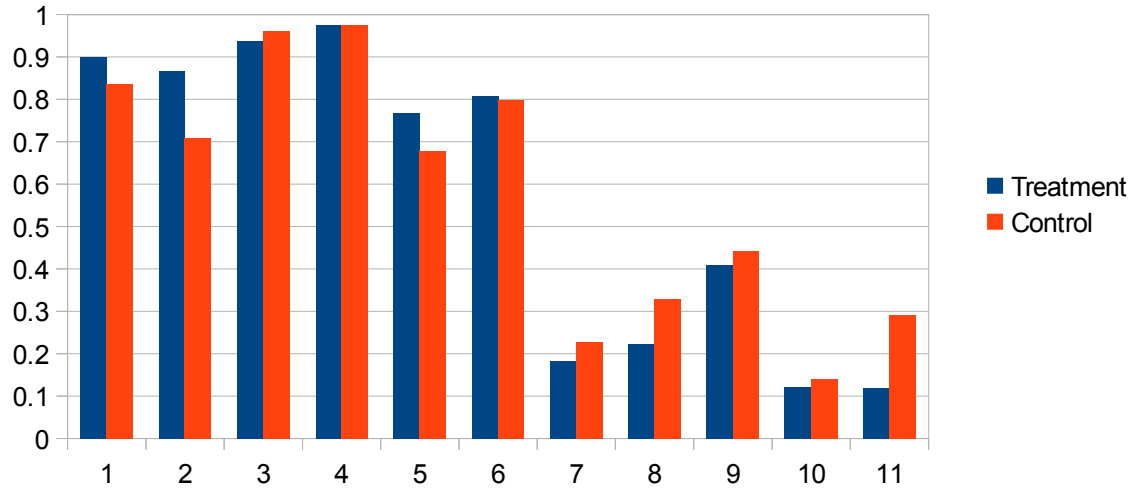


Figure 3 displays the proportion of "yes" responses for the fifteen questions related to desirability as seen in Table 1. The treatment has a higher proportion of "yes" responses for nine of the questions and the control has a higher proportion of "yes" responses for the remaining six questions. However, questions 4-7, 9, and 11-13 have only a 1% difference in proportion between treatment and control, so these proportions are essentially the same. Questions 1-3, 8, 10, 14, and 15 have a 2% or higher difference between the proportions and these could be considered important. Note that the treatment has a higher proportion of positive responses to the question "Do you like science?", "Do your parents expect you to do well in science?", and "Is science important for you to learn?", whereas the control has a higher proportion of positive responses to the questions "Do you like math?", "Do you want to learn math?", "Will you use math when you are an adult?", and "Will you use science when you are an adult?" From this exploratory data analysis, the unexpected result is that the treatment has a higher proportion of positive attitudes toward science, whereas the control has a higher proportion of positive attitudes toward mathematics with the exception of the question "Will you use science when you are an adult?"

Capability Factor. For the capability factor the assumptions were met for several of the questions such that multiple hypothesis tests to compare proportion of "yes" responses could be completed. Before examining these results, descriptive analyses were completed on the eleven questions, and these are summarized in Figure 4. Because questions 1-6 are positively worded, comparisons were made to determine whether there was a higher proportion of "yes" responses in the treatment group than in the control group. Because questions 7-11 are negatively worded, comparisons were made to determine whether there was a lower proportion of "yes" responses in

the treatment group than in the control group. As can be seen in Figure 4, the treatment does have a higher proportion of "yes" responses to questions 1-6, with the exception of question 3, and a lower proportion of "yes" responses to questions 7-11, which could indicate that students in the outreach program have more positive attitudes toward mathematics and science.

Figure 4: Proportions for Capability Factor



To analyze this result further, hypothesis tests were completed. Of the eleven questions relating to the capability factor, five of the questions (1, 3, 4, 10, and 11) failed to meet the assumptions required for the hypothesis tests so the analysis could not be run. The remaining six questions met all assumptions, and hypothesis tests were completed on these questions. The p-values for the one-sided hypothesis tests are provided below in Table 2. Significant p-values are highlighted in Table 2 for an alpha level of .05. Note that the three science questions have significant p-values, whereas the three mathematics questions have insignificant p-values.

Table 2: P-values for Capability Questions

Question	P-value
2. Are you good at science?	0.010
5. Is science easy for you to learn?	0.049
6. Is math homework easy for you?	0.290
7. Is math difficult for you?	0.148
8. Is science difficult for you?	0.046
9. Do you have trouble solving math problems?	0.693

From this analysis, there is statistical evidence to indicate that the treatment has a higher proportion of positive attitudes toward science than does the control with respect to the capability factor. No such result was found for mathematics.

Discussion

To summarize the results for the questions relating to the desirability factor, there is a higher proportion of positive attitudes toward science in the treatment versus the control, while there is a higher proportion of positive attitudes toward mathematics in the control versus the treatment. Overall, there was not much variability within the proportions for these questions relating to desirability and the proportions were high, which indicates that both elementary students in the Bechtel K-5 Educational Excellence Initiative and not participating in the program desire to do well in both mathematics and science.

To summarize the results from the hypothesis tests for the questions relating to the capability factor, there is statistical evidence that the proportion of positive responses to three of the science questions is higher in the treatment than in the control. In other words, for the students who have participated in the Bechtel K-5 Educational Excellence Initiative, these students have a higher proportion of positive attitudes toward science than students who have not participated in the program. There is not statistical evidence to indicate that the proportion of positive responses to the three mathematics questions differs significantly in the treatment versus the control. Students who have participated in the Bechtel K-5 Educational Excellence Initiative do not differ from students who have not participated in the program with respect to their attitudes toward mathematics.

One interesting result from this study is that there is not statistically significant evidence to indicate that students in the outreach program have different attitudes toward mathematics when compared with students not in the program. Since research supports the implementation of STEM education into the elementary schools in an effort to bolster students' attitudes and knowledge in STEM related fields, this suggests that our outreach program may need to be refined[6]. The goal of this outreach program is to encourage students to enter into a STEM related career. In order to achieve this, it is essential that students become confident and capable within mathematics because mathematics underlies all of the STEM disciplines.

Further work is necessary concerning the impact of this outreach effort on students' attitudes toward mathematics. Why is there no significant difference in the proportion of positive attitudes toward mathematics in the treatment versus the control? Possibly, the graduate students who participated in this investigation dedicated more of their classroom support to science than they did to mathematics or the teachers in the control group emphasized mathematics more than the teachers in the treatment group, and this preference may be internal to the teacher rather than program related. In response to our research questions, there was evidence to support that the students who participated in our program had a better attitude with respect to their own capability in science. Unfortunately, we were unable to find a direct link between these attitudes and the program.

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