AC 2010-1968: MIDDLE SCHOOL SUSTAINABLE OUTREACH? FUN ACTIVITIES IN MATH AND ENGINEERING: A 2-YEAR CASE STUDY

Althea Smith, North Carolina State University
Althea Smith is a PhD candidate in Biomathematics in the Department of Statistics. She earned her B.S. in Mathematics from Stony Brook University in 2004 and a M.S. in Biomathematics from North Carolina State University in 2007. Althea is a former graduate Fellow of the RAMP-UP program from the years 2006 to 2009. She is looking forward to obtaining her PhD in August 2010.

Elizabeth Parry, North Carolina State University
Elizabeth Parry received her B.S. in Engineering Management-Mechanical Engineering from the University of Missouri-Rolla. After working for IBM for 10 years, Mrs. Parry left to raise her children and start a science education business. Since 1999, she has directed two major grant programs for the College of Engineering at North Carolina State University. Currently, she is the Project Director for the RAMP-UP program.

Laura Bottomley, North Carolina State University
Dr. Laura Bottomley is the Director of the Engineering Place in the College of Engineering. She has been a Principal Investigator of the RAMP-UP program for the past ten years.

Lynn Albers, North Carolina State University
Lynn Albers is a Ph.D. Candidate in the Mechanical and Aerospace Engineering department. She has been a Graduate Fellow in the RAMP-UP program since the fall of 2005. She received her B.S. in Mathematics with a minor in Music from MIT and her M.S. in Mechanical Engineering with a minor in Nuclear Engineering from Manhattan College.
Abstract

It has been well documented that out-of-time STEM programs positively impacts the students and facilitators involved. However, we have yet to understand the sustained impact of middle school afterschool programs on its stakeholders. RAMP-UP (Recognizing Accelerated Math Potential in Underrepresented People), a National Science Foundation funded GK-12 outreach program at North Carolina State University (NCSU) has established the Fun Activities in Math and Engineering (FAME) at a local inner-city middle school. The facilitators of FAME were undergraduate and graduate Fellows and middle school math teachers. The objectives of this program were to re-enforce basic math concepts learned in the classroom and to expose the students to several fields of engineering while involving in hands-on engineering activities. For example, the activities incorporated understanding the key principles of engineering design, mathematical estimation and extrapolation, and how to appropriately collect data - skills which are clearly cross-disciplinary.

The FAME program was conducted weekly on a semester basis for 2 years (Fall 2007 through Spring 2009). Quantitative data in the form of surveys were collected at the end of each semester for the students involved. In addition, qualitative assessment data from the facilitators has been collected. In this paper we use the FAME program as a case study to evaluate the sustained impact of middle school after-school programs. This study reveals the positive relationship between the students and facilitators, and improved student and facilitator attitudes towards STEM fields throughout the 2-year period.

Introduction

Participation in afterschool programs has been shown to be associated with educational success including greater engagement in learning and higher academic performance. Programs based in the science, technology, engineering and mathematics (STEM) have often shaped and developed future scientists. For students to succeed in STEM fields Jolly, Campbell and Perlman suggest the necessary trilogy: engagement, capacity and continuity. Meaning students are engaged by having interests and motivation for the involvement in the sciences, student have the capacity or required skills needed to advance in these disciplines and students have the academic support and material resources (continuity) needed for these interests. After-school programs can provide a vehicle for realization of this trilogy outside of the classroom.

STEM based university and industry outreach programs have proven to greatly impact the community they serve. However, sometimes university or industry supported STEM outreach programs are comprised of a one day activity/demonstration exposing the youths to STEM fields. Though great in their attempts, these one day programs fail to develop mentor relationships between students and facilitators. It is this mentorship that has proven to profoundly impact the views of STEM fields of the students participating in these programs. We define sustainable STEM outreach as a partnership that maintains, fosters and promotes long-lasting interests in STEM fields.
RAMP-UP (Recognizing Accelerated Math Potential in Underrepresented People), a National Science Foundation funded GK-12 outreach program at North Carolina State University has established the weekly Fun Applications in Math and Engineering (FAME) at a local inner-city middle school. The aims of this afterschool program were to expose students to several areas of applied mathematics and engineering by engaging in hand-on activities, and reinforcing basic math skills while tutoring. In this paper we use the FAME program as a case study to evaluate the sustained impact of middle school after-school programs. This study reveals the attitudes toward math and science for the students, and the mentorship role of the facilitators involved in the FAME program.

Program description

**RAMP-UP**

RAMP-UP is a partnership between North Carolina State University and Wake County Public School System that is funded by grants from the National Science and GE Foundations. The program consists of principle investigators, an engineering project coordinator, graduate Fellows, and undergraduate Fellows in science, technology, engineering or math (STEM) and secondary math education. The undergraduate Fellows work with teachers at local public schools to plan and implement inquiry-based mathematics lessons that demonstrate the practical application of mathematical theory in the classroom. The graduate Fellow serves as a mentor for the K-12 students and undergraduate Fellows, and coordinates the program at their respective schools. The graduate Fellow also works to establish tutorial programs and clubs before and after school, helps with science fairs and coordinates family math nights to service the community.

**Fun Applications of Math and Engineering (FAME)**

In 2006, a pilot FAME program was developed at a local middle school. Students (6th - 8th grade) were recommended by their math teachers to participate. Once a week for an hour, students would engage in hands-on engineering based activities facilitated by a graduate Fellow, undergraduate Fellows and a math teacher. Roughly ten students were recommended for this program, however maintaining attendance at times proved difficult. In addition, the structure of the school day did not support the maintenance of this pilot program. The school day began at 7:30 in the morning and it was difficult to retain students until 5pm, when the school transportation was available. The FAME program was did not continue at this school.

The structure of the school day at another RAMP-UP supported middle school was more conducive to administering an afterschool program. In the spring of 2007, RAMP-UP launched the FAME program at this school from 3:20 pm - 4:50 pm each Wednesday for roughly 7 weeks. The first 50 minutes were allotted for the tutorial, where students received help with homework and understanding core mathematical concepts and the remaining 40 minutes were dedicated to the math/engineering activity. As in the previous pilot program students were recommended by their math teachers to participate.
However, unlike the pilot program in the spring 2007 there was an open invitation (with a permission slip provided by their teacher) each week for students to attend this program. Thus, there was not necessarily the same group of children in the program each week. More than often the same students would regularly attend. On average about 18 students each week participated in FAME during the spring of 2007.

In the fall 2007, the FAME program was continued at this school and the interest for this program nearly doubled to about 35 students participating each week. The support staff increased to 4 undergraduate Fellows and the children were divided into two classrooms in order to have enough space for the activities. In the spring of 2008, it was suggested that each math teacher (9 math teachers total in this school) only recommend 2 students each week and the students had to provide a signed permission slip each week. On average 15 students participated each week in the spring of 2008. The program continued at this school in this fashion each semester and on average 10 and 7 students participated in this program in the fall 2008 and spring 2009 semesters respectively. From 2007 onward at the beginning of each semester the Fellows took 5 minutes to talk about themselves and their future career plans. In addition, throughout the program we held open forums where students asked questions to the Fellows on any topic at the closing of each activity. Table 1 details the structure of the FAME program at this school throughout the 2-year period.

Table 1. Description of FAME from 2007 through 2009.

<table>
<thead>
<tr>
<th>Date implemented</th>
<th>Spring 2007</th>
<th>Fall 2007</th>
<th>Spring 2008</th>
<th>Fall 2008</th>
<th>Spring 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants</td>
<td>1 Graduate Fellow</td>
<td>1 Graduate Fellow</td>
<td>1 Graduate Fellow</td>
<td>1 Graduate Fellow</td>
<td>1 Graduate Fellow</td>
</tr>
<tr>
<td></td>
<td>1 Math Teacher</td>
<td>2 Math Teacher</td>
<td>1 Math Teacher</td>
<td>1 Math Teacher</td>
<td>1 Math Teacher</td>
</tr>
<tr>
<td></td>
<td>2 Fellows</td>
<td>4 Fellows</td>
<td>3 Fellows</td>
<td>3 Fellows</td>
<td>3 Fellows</td>
</tr>
<tr>
<td>Average number of students / session</td>
<td>18</td>
<td>35</td>
<td>15</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Number of sessions held</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

Algebra, geometry, and basic physics of motion and force were some of the topics that the student explored. During the activities students learned, algebraic relationships, graphing skills and how to interpret data they collected.

*Hands-on Activities*

Activities were administered by RAMP-UP Fellows. In the spring of 2008, each undergraduate Fellow facilitator was required to lead the students through at least one activity. The activities covered the topics of algebra, geometry, and core physics principles. The students were also exposed to the key principles of engineering design, learned how to collect data and how to use measurement tools accurately. Many of the activities were taken from math or engineering resources where they were adjusted for the time allowance or age group of the students, while other activities were uniquely developed by the Fellow. Students also learned to work in collectively in groups and
were encouraged to work with students not in their math class and grade level. Examples of some of these activities are detailed below.

1) Polyhedra Earthquake
   Students learned how engineers construct sturdy buildings by introducing them to the concept of regular polyhedrons. Students were instructed to build a sturdy building from toothpicks and marshmallows and calculated the volume and surface area of these structures. Finally, their structure had to withstand a simulated earthquake when placed in a pan of Jell-O.

2) Foil Boats
   Students were given 4 pieces of foil paper and instructed to build boats that would support the weight of 50 glass beads in water. The students designed one boat (a prototype) at a time, tested it and made an improvement, if necessary, to the next boat. The students recorded their observations for the 4 boats and made a bar graph of their results.

3) Puff Mobile
   Students were instructed to build a mobile device that would travel the furthest distance using paper, circular candies and straws as materials. Figure 1 (a) shows the final competition of vehicles who traveled the furthest with a gust of air.

4) Magnetic Accelerator
   Students were given an introduction to the properties of magnets. The students were then instructed to build an accelerator using 2 magnets, tape, a ruler and small steel balls (Figure 1 (b)). As they increased the number of magnets on the ruler this increased the speed that the ball traveled.

Figure 1. (a) Students lining up for the Puff Mobile race, (b) Students explaining and testing their Magnetic Accelerator.
Methods

Data from the FAME program was collected in the form of surveys from students in FAME during the fall 2007 (N = 29), spring 2008 (N = 22), fall 2008 (N = 11) and spring 2009 (N = 9). All surveys were administered by Fellows. The objective was to obtain students' opinions on math and their perception of FAME. Some questions had responses of “yes a lot”, “yes”, “some”, “no”, “not at all”; while other questions were based on a Likert scale (1 = strongly disagree, 2 = disagree, 3 = neither agree or disagree, 4 = agree 5 = strongly agree). The Likert questions revealed students' confidence in math, their perception of their math teacher and the ideal of math being a male dominant area of study. In the spring of 2008 another survey was administered to Fellows and teachers administering the FAME program; the details of this survey were examined in Albers et al.¹.

Results

Attitudes Towards FAME

The following questions or comments were posed to students to assess their perception of the program: “Do you enjoy working with the RAMP-UP Fellows?”, “I think the RAMP-UP Fellows really help me understand math better”, “I think the RAMP-UP Fellows really help me understand math better”, “I am more interested in attending college after working with RAMP-UP students” and “The RAMP-UP activities and lessons are fun”. The results from the 2-year study are provided in Figures 2 through 6.

Do you enjoy working with the RAMP-UP Fellows?

Figure 2. Attitudes of Students Toward Fellows and Activities During FAME in response to the question: “Do you enjoy working with the RAMP-UP Fellows?”
Figure 3. Attitudes of Students Towards Fellows and Activities During FAME in response to the comment: “I think the RAMP-UP Fellows really help me understand math better”

I think the RAMP-UP Fellows really help me understand math better

Figure 4. Attitudes of Students toward Fellows and Activities During FAME in response to the comment: “I am more interested in attending college after working with RAMP-UP students”

I am more interested in attending college after working with RAMP-UP students
I am more interested in studying math, science or engineering after working with the RAMP-UP students

The RAMP-UP activities and lessons are fun

More than 80% of the students over the 2 year study agreed that they enjoyed working with the RAMP-UP fellows. This may also be attributed to the fact that some of the RAMP-UP Fellows were also in their classrooms weekly, and this added presence may have influenced their positive views. In addition, teachers would comment that students were eager to attend FAME each week and despite the fall 2008 results, the students in
general enjoyed the activities. Moreover the students answers revealed that the Fellows influenced their better understanding of the math concepts (Figure 3). After spring 2008, there was a decline in the students views of attending college and studying STEM fields (Figures 4 and 5).

Fellows and teachers who participated in FAME were surveyed in the spring of 2008. In response to the question: “Have you noticed an improvement in learning attitude and classroom participation of a student(s) who participated in the Afterschool Program?” one teacher responded: “Students enjoyed the afterschool program and seemed to have a better attitude towards math class”. This re-enforces the ideal that students participating in afterschool programs have greater engagement in learning.

**Attitudes Towards Math**

Students attitudes toward math were exceeded over the 2-year period and are reported in Figure 7. The comments “I know I can learn math”, “Math is easy for me”, “I am sure of myself when I do math”, “Math has been my best subject”, “I think I could handle more difficult math”, “I can get good grades in math”, “I am no good at math” were used to access the students confidence in math. The comment “Girls are as good as boys in math” we used to access the students views of math as a male field.

![Figure 7. Attitudes Toward Math for Students Participating in FAME. The error bars represent the standard deviation among the students surveyed. The range of responses was from 1-5 on the following Likert scale: 1 = strongly disagree, 2 = disagree, 3 = neither agree or disagree, 4 = agree and 5 = strongly agree.](image-url)
Overall, the response to confidence in math ability and the view of math as a male field highly varied throughout the semesters (Figure 7). In some semesters confidence increased while in other semesters students’ confidence decreased. This may be attributed by a number of factors including the grade level of the student, and their grades in the classroom and thus may not be an indicator of the FAME programs’ influence on the students’ attitudes about math.

**Discussion**

The RAMP-UP sponsored sustainable outreach program has shown to positively impact the participating students. According to Bouffard et al. “Linkages between Out-of-Time [programs] and universities can facilitate the postsecondary transition by educating youth about their options for the future and preparing them to apply and to succeed in college”\(^2\) Overall the FAME program has provided a vehicle for STEM exploration, as its facilitators proved to be role models for students. Providing role model mentors, opportunities to participate in after-school mathematics-related club activities, may be ways of supporting student achievement and confidence in mathematics.\(^5\) Though the results of this 2-year study were variable, it re-enforces the need for STEM based afterschool programs in middle schools.

**Acknowledgements**

We would like to thank all the undergraduate RAMP-UP Fellows who have helped to facilitate the FAME program throughout the years and the cooperative teachers and staff at the middle schools who administered this program. Special appreciation is extended to Ms. Sonya Patel who has shown great leadership skills in the FAME program. We would also like to acknowledge the math teachers both past and present at our middle schools who have invested countless hours to help their students; especially Mrs. Ann Mitchell, Ms. Jennifer Wygal, Mrs. Jessica Krager, and Mr. Matthew Robinson.

**References**


