Impact of a STEM-focused Research Program on Minority High School Students’ Self-Efficacy and Interest in STEM Research and Careers (Work in Progress)

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Introduction

This work in progress study describes the impact of a STEM-focused research methods course and summer research experience on the self-efficacy and interest in STEM research and careers of underrepresented high school students (grades 9-11) in the Mathematics and Science Education Network Pre-College Program (MSEN). The minority engineering program (MEP) at North Carolina State University partnered with MSEN to develop the course and summer experience. Both project components were designed to provide exposure to research methods, engineering design principles and STEM careers and professionals. Undergraduate students in the MEP served as mentors to the MSEN students throughout the research methods course and summer research experiences.

It is widely accepted that the U.S. must produce more highly skilled individuals in the STEM fields in order to maintain its global competitiveness. According to an executive report issued by the President’s Council of Advisors on Science and Technology (PCAST), the U.S. will need to increase the number of students who receive undergraduate STEM degrees by about 34% annually over current rates to meet future workforce demands\(^1\). Changing the nation’s approach to STEM education includes bringing more minorities and other traditionally underrepresented groups in STEM into the fold, as it has been projected that ethnic minorities will account for more than 50% of the U.S. population by 2050\(^2\).

A number of studies have suggested a link between self-efficacy and attainment of STEM degrees by underrepresented minorities\(^3,4,5,6\). Self-efficacy refers to a person’s belief in his or her ability to successfully perform a given task or behavior\(^7\). According to Bandura\(^7\), self-efficacy determines the course of action people choose to pursue, how much effort they put forth in given endeavors and how long they will persist in the face of obstacles. The aim of this study is to evaluate the impact of exposure to STEM through informal STEM research experiences on underserved and unrepresented students’ self-efficacy and interest in STEM research and careers.

Program Overview

A research methods course was developed for high school students (grades 9-11) in the MSEN program and is being taught in three parts over the duration of the three year project period: introductory-9th grade, intermediate-10th grade and advanced-11th grade (Fig. 1). Students entered the program as ninth graders and continued through to the junior year. The course was designed to provide

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**Figure 1. Pre-College STEM Research Experience Model**
exposure to research methods in STEM, engineering design principles and STEM careers and professionals. Course topics included research and career opportunities in STEM, the scientific method, engineering design process, data collection and analysis, fundamentals of Microsoft Excel and statistics. Each part of the course consisted of 10 class meetings for two hours per meeting as a part of the MSEN Saturday Academy. Class sessions were held in an academic building on the campus of North Carolina State University.

**Course Learning Outcomes**
At the conclusion of the course students should be able to:

1. Define the term research.
2. Describe examples of research being conducted in STEM fields and the potential impact of that research on society.
3. List examples of career opportunities available in various STEM fields.
4. Collect scientific data in a laboratory setting.
5. Analyze and interpret simple scientific data generated in the laboratory.
6. List and describe the steps of the scientific method.
7. List and describe the steps of the engineering design process.
8. Compare and contrast the scientific method and the engineering design process.
9. Describe the difference between quantitative and qualitative data and provide examples of situations where each is used.
10. Demonstrate knowledge of the basic functions of Excel and how it can be used in scientific data analysis.

Students participated in a 2-week long summer research experience in years 1 and 2 of the program where they worked on engineering design-focused research projects under the guidance of MSEN teachers and MEP mentors. MSEN students were required to complete the research methods course in order to participate in the summer experience. In year 3, students will participate in a 1-month summer research experience where they will live on campus and work 35 hours per week in a STEM faculty member’s lab on a small research project.

Selection criteria for program participation included: 3.0 GPA in 8th grade, completed Common Core Math II and achieving a 3.0 GPA in the first semester of the 9th grade year. Due to additional space being available in the course, additional students were added if they had at least a 2.75 GPA in eighth grade and met the other two criteria for selection.

This paper summarizes the results for the first two years of the program. The third and final year is currently underway.

**Program Implementation**
Initially, 43 ninth grade students were invited to participate in the program but only 37 agreed to participate. In year 1, the average number of participants each Saturday was 27, but ranged from 22 to 31 across the ten class sessions. In year 2, the average number of student participants each Saturday was 29, but ranged from 20 to 33 across the ten sessions. Four students left the program after year 1 for various reasons. Three new students were added to fill those vacancies resulting in a total of 36 student participants in year 2. Table 2 provides greater detail about student demographics.
**Year 1**

The course began with a basic orientation and overview of the elements of scientific research and the engineering design process. Subsequent sessions were focused on exploring the science and engineering of prosthetics. Students conducted research, designed a prosthetic limb, developed a materials list and budget and created a prototype limb based on their design.

Program participants spent nine full days on campus during the summer experience. Students explored transportation systems research and engaged in extended learning opportunities including campus tours, industry tours and presentations from invited guest speakers. The summer research experience focused on the Engineering Grand Challenge, Restore and Improve Urban Infrastructure. Students learned the history of autonomous vehicles and how to program Lego® Mindstorms® NXT-G to simulate car movement through various traffic situations. They wrote a paper detailing their experience, created a PowerPoint, and presented their findings to a session with parents and University faculty.

**Year 2**

The first half of the course focused on the Grand Challenges for Engineering. Students conducted hands-on research methods connections activities related to several of the grand challenges. The theme of the second half of the course was “Engineering Challenges in Flight and Space” with a focus on drone technology. Students conducted preliminary research on drone technology including communications, power systems and propeller/motor design. The research was presented by the students during a poster session held on the last day of the course.

Participants spent ten days on campus as a part of the year 2 summer experience. Students explored drone technology research and continued to engage in extended learning opportunities. The preliminary knowledge of drones gained in the course allowed students to delve deeper into drone technology research, including exploration of the current state of the technology, applications of the technology and the impact of drones on our society. Student teams examined the effect of component mass on the battery life of drones. Each team created a PowerPoint presentation highlighting their findings at the end of the summer experience.

**Evaluation**

The evaluation of this project has been informed by a variety of sources, including program artifacts, observations, focus groups/interviews, and surveys. The following questions guided the evaluation:

1. Did the program staff create and implement a high quality, engaging research methods course and summer research experience.
2. To what extent did participation in the program impact students’ science and mathematics competency levels?

**Table 2. Student Demographics**

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<tr>
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<th>Year 1</th>
<th>Year 2</th>
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<tbody>
<tr>
<td><strong>Race</strong></td>
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<tr>
<td>African American</td>
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<td>67%</td>
</tr>
<tr>
<td>Female</td>
<td>41%</td>
<td>33%</td>
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</tbody>
</table>
3. To what extent did participation in the program impact student enthusiasm for science and mathematics?
4. To what extent did participation in the program impact student interest in pursuing careers in research or other science-related areas?

**Project Documents and Artifacts**
Program documents and artifacts were used to help inform evaluation efforts and to ensure the data collection instruments developed were closely tied to the program design and goals. They were also used to assess whether it was aligned to the priorities of the funding agency.

**Research Course Development and Implementation, Summer Research Experience Observations**
Non-intrusive site observations occurred during the research course development process. These observations were conducted during select planning meetings. Informal visits were made during the research course and summer research experience. Detailed field notes were gathered and analyzed to provide requisite answers for the evaluation questions.

**Focus Groups and Interviews**
MSEN teachers, student participants, and mentors participated in either focus groups or interviews to determine the program’s impact on the items outlined in the evaluation criteria. Semi-structured interview protocols were used to guide discussions with participants. Interviews and focus groups were digitally recorded and transcribed. A reflective analysis process was used to analyze and interpret interviews and focus groups.

**Test of Students’ Science Knowledge**
A student science content knowledge assessment aligned to the instructional goals of the research course was developed and administered at the onset and conclusion of each part of the course.

**S-STEM Survey**
The S-STEM Student Survey measures student self-efficacy related to STEM content, interest in pursuing STEM careers, and the degree to which students implement 21st century learning skills. The survey was administered in a pre/post format at the beginning and end of each project year.

Evaluation data from the first two project years show that the STEM research program was successful in creating experiences that were high-quality and engaging. Instructors utilized project-based learning strategies to facilitate learning objectives. Students were encouraged to reflect on their experiences and what they had learned throughout the course.

Through observation during the school year and summer sessions, students were found to be highly engaged with their projects and exhibited high levels of on-task behavior. Students appeared to enjoy the time they spent working on their various projects. When asked during the student focus groups, one student compared her experience in this program to programs that were attended in the past,

_This is the best one that I have done, in my opinion. The most fun one ever. We’re not even using the real resources they use to make a real medical prosthetic leg. We’re just using foam and pipes. It’s cool that everyone has the imagination and creativity to make it out of normal stuff._
One student described the program as “fun”; while, another student elaborated by saying, “It’s fun because you get to have new experiences.” Similarly, when asked about how the program compares to their science classes in school, several of them expressed that many of their school courses lack a hands-on aspect. As a result, several of the students felt the manner in which the program was designed helped them understand the content better. Overall the students rated the program content, teaching/learning techniques, and staff support very high. One student shared,

“We have college students who come help us, so they better understand, if we don’t understand something that would help us understand in a way that older people would explain it to us. I really liked how the college students came to help us. I mean not even just with the college students. The teachers are helpful, too.

The program had a positive impact on student enthusiasm for science and to a lesser degree mathematics according to students, the lead teacher, and mentors. By virtue of the students tapped for the program, most had high levels of enthusiasm before the onset of the program. The lead teacher commented in an interview on how student enthusiasm increased as the course progressed and that students that were initially quiet and reserved began to come out of their shell.

The program piqued most students’ interest in potential careers in a STEM-related field. When asked what fields they might want to pursue, several mentioned various forms of engineering and medicine or medical research. Different students said,

*I feel like it strengthened whether or not I want to be an engineer.*

*I never really thought about engineering, to be honest. It was never something that I really thought about in depth but find it interesting now.*

The S-STEM provided information about how interested students were in a predetermined set of STEM areas. Survey results showed that the biggest jump in interest was seen in engineering. It held in the high seventies in year one and increased to 91% overall in year two. Upon comparing STEM preferences between gender on the post-test, girls expressed greater interest in medicine and medical research than boys. On the other hand, boys showed greater interest than girls in engineering, physics, and computer science.

A few students remain unsure about their career interest. However, the research methods course proved to still register impact. The course affected one of the students in a profound way in terms of him beginning to see that he has the aptitude to be a STEM professional even if he opts not to. He said,

*I am not sure that I want to be an engineer, but I know that if I wanted to and put my mind to it I could. The ones I have met are regular people.*

Although, the student may not pursue engineering, the course was successful in building student confidence and providing information about the possibilities of what can be. Career paths are not limited.

One student expressed that she is still undecided about her major. She initially entered the program with a strong interest in medicine, but the exposure to engineering has her thinking about exploring engineering options. She stated,
Even if I choose to go back to my first love of medicine, I see the benefit in learning the engineering concepts. I see how the engineering process can be used in every aspect of life.

Opportunities for Improvement & Future Outlook

There were four major areas identified in the evaluation where improvements could be made. The first was the greater focus on engineering in the introductory course in year 1. While this caused a surge in interest in the engineering fields among males, it may have alienated some of the female students who expressed greater interest in the medical field. In year 2 of the project, program staff offered a class session on the Advance Health Informatics grand challenge and it was well received. We are continuing to be more intentional in incorporating more of the medical sciences into the course activities and summer experiences. Secondly, we scaled back on the number of guest speakers and tours in year 2 and the students expressed their displeasure with this change. They truly valued those interactions and therefore, we are including more of those experiences in the final year. Thirdly, students overall felt that their math knowledge remained the same and was not improved due to the program. One of the goals going into year 2 was to more closely align math and science concepts to course activities, thereby allowing students to build both science and math skills throughout the program. Finally, efforts must be made to clearly distinguish research from engineering design. The focus in the final year has been to ensure that research practices are covered in more detail so that students are adequately prepared for the final summer research experience in a STEM faculty lab. At the conclusion of this program, we aim to explore the longitudinal impact of the program on students’ decision to pursue STEM studies.

References