Enhancing K-12 Outreach Programs Through the Implementation of Discipline Specific Demonstrations

Emily McCabe and Morgan Green
Department of Mechanical Engineering, Mississippi State University

Abstract

As K-12 outreach has continued to take hold across the country, teams have begun to focus on altering outreach content for improved outcomes. The development of engineering outreach content is affected by numerous variables including target audience age, funding, and program duration. This study focuses on the impact of adding major-specific demonstrations to the content of Project ENspire at Mississippi State University. Project ENspire is a half-day outreach program for 4th and 5th grade girls and has been offered in Starkville, MS since 2016 and in Olive Branch, MS since 2018. Historically, this program's content has included a brief introduction to engineering paired with three open-ended design problems. For the 2019 sessions the open-ended problems were reduced from 3 activities to 2 activities and a rotation of major specific demonstrations was introduced. These demonstrations included topics specific to aerospace, chemical, biomedical, civil, electrical, and mechanical engineering. Demonstration volunteers were members of that specific field and facilitated discussions surrounding their particular discipline. Pre- and Post- Surveys were administered to participants since 2017 and this data will be evaluated. Observations by the Project ENspire Core Team will also be discussed.

Keywords

outreach, engineering disciplines, demonstrations

Introduction

Engineering outreach has become a part of several institutions as they work to engage, educate, and recruit the surrounding community. A major part of engineering outreach focuses on the K-12 community and can target any or all of these three goals. At Mississippi State University (MSU) one K-12 outreach program, Project ENspire, has worked with 4th and 5th grade girls in regional programming since 2016. Introduced by Green and Knizley in 2018[1], Project ENspire has since expanded to multiple locations and continues to work towards the growth discussed in the paper. Girls involved in Project ENspire worked in teams mentored by Mississippi State engineering students to solve open-ended, engineering-based problems. This type of programming helped to engage skills such as critical thinking, teamwork, and problem solving, as well as covered some basic engineering concepts such as Newton's Laws or friction. One component that was given less attention was engineering disciplines. Each year, the types of engineers were briefly discussed during the program welcome as mentors and their respective majors were introduced. It was observed that information regarding engineering majors and applications was not well retained in this format. The literature has already indicated success with demonstration based outreach as a way to effectively introduce topics to participants[2]. Additional research out of the Army Research

Laboratory has indicated the success of multi-modal programs. These programs use various methods such as lecture, example, and demonstration to convey content[3]. Using this information, a rotation of discipline demonstrations was integrated into the Project ENspire curriculum in 2019. This allowed for students to learn about engineering through several different methods such as example engineers during introductions, brief lectures, open-ended projects, and the demonstrations. An additional emphasis was placed on demonstration leader selection. Literature shows a synergistic relationship between students and their mentors. For these demonstrations, volunteers majoring in a given discipline were aligned with experiments where possible. This provided another way for children to be exposed to specific types of engineers and allowed mentors to convey confidence due to the experiences[4,5]. This paper will discuss the implementation of discipline specific demonstrations and compare the retention between the 2019 students and the preceding years.

Methods

Participants

The participants of the study are 4th and 5th grade attendees of Project ENspire (approximately ages 9-11 years old). All participants are female.

Instruments

Upon the completion of sessions from 2017-2019 participants were asked to complete pre- and post- surveys. The surveys are anonymous, and the questions did not yield any responses that lead to participant identifiers. Observations from core team volunteers were also collected. Sessions will be referred to by location (Olive Branch and Starkville sessions) and by year. Data was compiled from participant surveys, volunteer surveys, and core team observations to assess the efficacy of the demonstrations.

Design

Discipline specific demonstrations were integrated into the Project ENspire sessions in order to help participants better connect the skills they were applying with real-world examples. These examples included future career paths, engineering role models (provided by like-major volunteers), engineering examples in their daily lives, and engineers they may know in their life.

For the 2019 sessions of Project ENspire a set of demonstrations was integrated into the programming. There were six rotations to be completed in a one and a half hour period (10 minutes per rotation plus transition time). The rotations addressed the following fields of study:

1. Aerospace Engineering
2. Biomedical Engineering
3. Chemical Engineering
4. Civil Engineering
5. Electrical Engineering

6. Mechanical Engineering

Each rotation was comprised of several points including the name of the engineer, examples of professions and responsibilities of that engineer, some discipline specific concepts, a demonstration or activity, and a variety of interactive questions. Rotation content varied depending upon the level of hands-on content, and rotations were run by 2-3 volunteers. Rotation content for 2019 sessions will be specified later in this paper for each field of study.

Project ENspire used a volunteer recruitment program for the 2019 year. Recruitment included surveys which collected data related to interest, experience, classification, major, etc. Volunteers ranged from freshman to graduate student and represented each of the engineering departments on campus. All volunteers attended one training session which covered topics including the basics of engineering outreach, mentorship skills, and exercises in volunteering. Positions were described including positions related to the demonstrations. Following the training, volunteers were surveyed again regarding similar topics to the Pre-Training Survey. Survey results were used to select demonstration leaders in combination with position requests (also filed after training completion). Specific survey questions that were taken into consideration included:

1. Major
2. After viewing this material, how would you describe your knowledge of Engineering Outreach Principles?
3. On a scale of 1-10, how would you describe your confidence in your communication skills after this session?
4. On a scale of 1-10, how would you describe your confidence in your teaching skills after this session?
5. On a scale of 1-10, how would you describe your preparedness to work with children at Project ENspire after this session?
6. On a scale of 1-10, how would you describe your leadership skills after this session?

Using this data, 2-3 volunteers were assigned to each demonstration with aligning majors or experiences when possible. Demonstration Leaders underwent a short day-of training related to leading rotations and instructions for their particular demonstration/activity.

Procedure

In order to integrate the discipline specific demonstrations into the existing Project ENspire, content changes were made to schedule and curriculum. A one and a half hour period was reserved for the demonstrations and 15-18 volunteers were dedicated to demonstration rotations. Additional content was integrated into the Project ENspire curriculum, The Book of ENspiration. The Book of ENspiration was provided to girls at the beginning of the day and they were encouraged to take it home with them to try some of the experiments and/or demonstrations at home. Samplings from the "Experiments in Engineering" section of the book are found below in Figure 1.

Excerpt 1

"Biomedical Engineers work to help people by creating new medical devices, medicines, and treatments. When you go to the doctor, the X-Ray, vaccine, or cast you may have gotten were all created by biomedical engineers!"

Excerpt 2

"Today we're talking about how aerospace engineers utilize thrust. Thrust is the term used to describe the force that acts away from the rocket to launch it. We're going to create thrust by using pressure. Pressure is a force that acts perpendicular to the area of an object. This could be like the water pressure in the deep sea, or like the gas pressure we will see today."

Figure 1. Excerpts from the Book of ENspiration

The rotation content for the demonstrations worked to integrate fun, hands on activities with more discipline specific content. Demonstration leaders provided more guidance when compared to the open-ended projects and gave a small introduction about their type of engineer. The Demonstrations or "Experiments in Engineering" are listed below for each type of engineering in Table 1.

Table 1. Demonstration Content

Discipline	Demonstration	Concepts
Aerospace Engineering	Tiny Rockets	forces, thrust, pressure
Biomedical Engineering	Release Kinetics	Release kinetics, drug release
Chemical Engineering	Elephant Toothpaste	Reactions, exothermic
Civil Engineering	Concrete Shapes	Materials, concrete, aggregates, strength
Electrical Engineering	Spinning Heart	Circuits, motors, electrical energy, mechanical energy, electromagnetic fields, forces
Mechanical Engineering	Non-Newtonian Fluid	Flow, non-Newtonian fluids

Data Analysis

The survey data from 2017, 2018, and 2019 was analyzed both qualitatively and quantitatively. The variation and frequency of free responses was recorded. The number of responses for each Likert scale option was recorded and the percentages for each response were calculated. The percentages for pre- and post-surveys for 2018 and 2019 were compared to determine if the demonstrations led to an increase in the number of "agree" and "strongly agree" responses.

Results and Discussion

In 2017, Project ENspire held one session on the Mississippi State campus. Participants from this session filled out a pre-survey, administered at the beginning of the day and a post-survey completed at the end of the day. These participants completed three open-ended design projects and were not exposed to the demonstrations curriculum. Open ended design projects from the year 2017 were building a fan, an extendable arm, and a ping pong ball track. Results examined here address the question "I can name at least two kinds of engineers" where participants were asked to indicate disagree, maybe, or agree, with a blank space left for them to list engineers. Ten girls completed the Pre-survey and five girls completed the post survey. Pre-survey results found that 70% of participants could not name at least two kinds of engineers. Another 30% of participants marked maybe and filled the blank provided. Their answers are compared with the post-survey results found in Table 2. During the post-survey, 100% of participants agreed that they could name two kinds of engineers and their responses are also specified in Table 2. It should be noted that the responses are dictated as written.

Table 2. Free Responses from 2017 Pre- and Post- Surveys

Free Responses- "I can name at least two types of engineers."	
Pre-Survey	**Post Survey**
mechanical	mechanical, industrial
physical	mechanical, electrical
none	mechanical, biomedical
	biomedical, industrial
	mechanikle, elechial

In 2018, Project ENspire offered two sessions, one in Olive Branch, MS at Lewisburg Elementary School and one in Starkville, MS on the Mississippi State University campus. The sessions used the same curriculum which featured three open-ended activities and no demonstration content. The activities were a table-tennis ball zipline, a swinging ride, and a candy catapult. Both sessions also featured a bonus activity at lunch which covered simple thermodynamics concepts to make ice cream. Pre- and post-surveys were offered at both sessions and questions were completed on a 1-5 scale where 1 was strongly disagree and 5 was strongly agree. The 2019 sessions were held in the same locations at 2018. The format was a morning and afternoon open-ended activity with the demonstration rotation in the middle. The 2018 and 2019 years share the most similarities with regards to participation level and overall format of the event. These similarities allowed for a good comparison of the survey results for both years.

The percentage of participants who marked each of the five responses was calculated for both sessions from 2018 and 2019. The combined results are shown below in Figure 2. The combined results represent 41 and 36 respondents for 2018 and 2019, respectively.

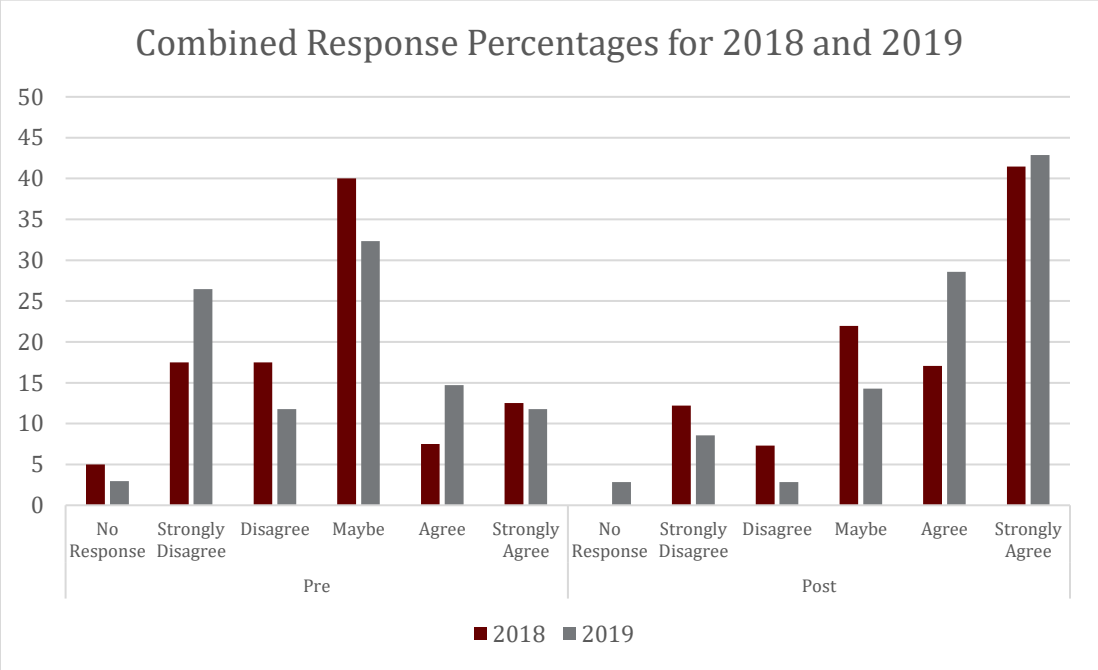

Figure 2. Combined Response Percentages for 2018 and 2019

The post-survey results show that in 2019 there was an increase in responses to "agree" and "strongly agree" with the "agree" response growing from 17% to 28%. The growth in both of these categories is attributed to the demonstrations in 2019 and the focus on specific engineering disciplines.

Additionally, the free responses to the question where examined and categorized based on their validity of being an actual engineering discipline. In 2018, not all of the engineering types that participants listed were valid engineering disciplines. The combined results showed that 83% of the responses were valid engineering disciplines. However, in 2019, 100% of the responses in both sessions were valid engineering disciplines. The results are shown graphically in Figure 3.

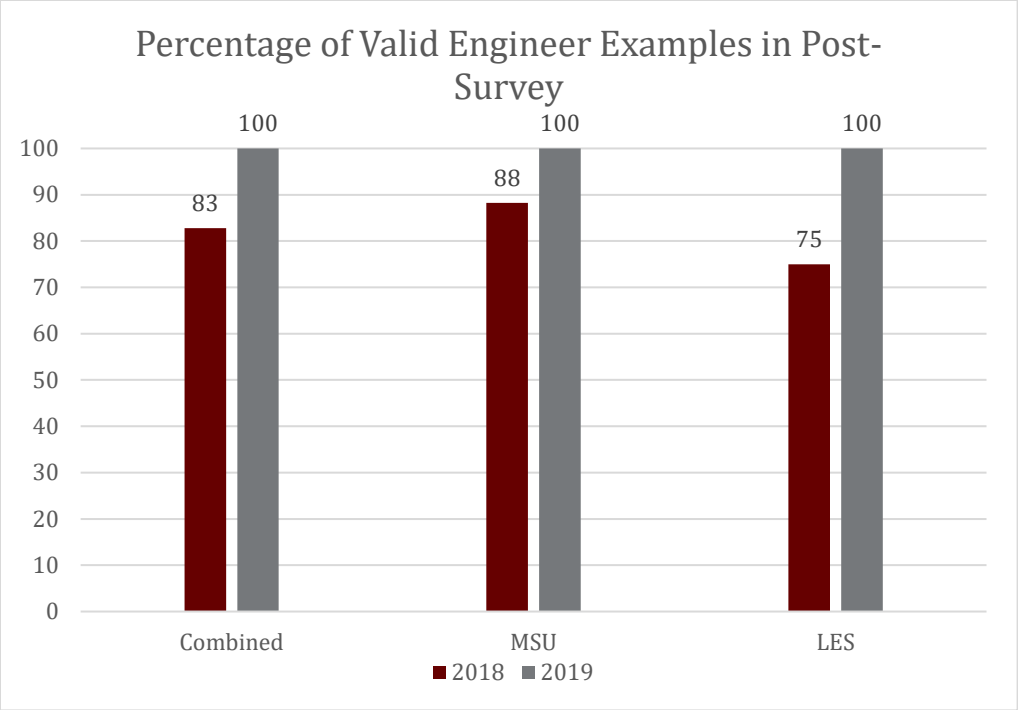

Figure 3. Percentage of Valid Engineering Examples in Post-Survey

Observational Data

As mentioned previously, it was observed that participants showed growth in soft-skills such as teamwork and critical thinking, but they showed less retention of engineering specific experiences. Upon the implementation of the demonstrations the core team of Project ENspire was interviewed. The Core Team consisted of faculty advisors and graduate students.

Responses related to training were positive. Core Team observed that those volunteers present at additional training and test sessions were stronger in understanding and confidence which made them better leaders. With regard to the demonstrations, Core Team felt that the leaders utilized diverse communication skills through answering questions and presenting demonstrations. The Core Team also observed that demonstration leaders did additional research outside of the program to provide a well rounded experience to the subject. Overall, Core Team noticed a positive response from the participants as they were leaving and that repeat participants had a better time with the new format. Future directions noted by the Core Team may include a more career-related visual aid to enhance the engineering discipline discussion.

Conclusions and Future Work

A goal of Project ENspire is to introduce the 4th and 5th grade participants to all that engineering has to offer. Through activities throughout the day, participants see examples of what engineers do. In the first few years of the event, girls were introduced more in depth to engineering

disciplines most applicable to the open-ended activities that were completed. Other engineering disciplines were only introduced through conversations. In 2019, a new aspect of discipline-specific interactive demonstrations helped to give substance to the explanations of engineering disciplines that were not covered in the open-ended activities. Surveys administered to participants showed a growth in the knowledge of engineering disciplines in 2019. From 2018 to 2019, the percentage of girls who said they could name a type of engineering increased. Every girl who listed engineering disciplines listed actual disciplines. Due to the success of the 2019 demonstrations, the 2020 sessions of Project ENspire will also include demonstrations. A team has been created that is dedicated to developing and designing activities and demonstrations that will give the most exposure to numerous engineering disciplines.

References

1. Green M, Knizley A. Planning , Implementation , and Impact of K-12 Outreach Program Project ENspire. 2018.
2. Kelkar A, Azzi E, Ryan T, Ryan J. STEM Outreach Using In-House and Mobile Demonstrations. *J STEM Educ Innov Res*. 2018;19(4):35-41.
3. Foots A, Gaston JR, Pollard KA, Mermagen T. Auditory Demonstrations for Science, Technology, Engineering, and Mathematics (STEM) Outreach. 2015;(January). doi:10.13140/2.1.3631.9528
4. Manuel M, Greer RP, Henderson JA, Rangel VSR. Engagement in practice: STEM engagement through mentoring. *ASEE Annu Conf Expo Conf Proc*. 2018;2018-June.
5. Nguyen LTN, Rocha LM, Nguyen CBC, Houchens BC, Bautista-Chavez AM. Volunteerism in engineering outreach: Motivations and surprising outcomes for undergraduate mentors. *Proc - Front Educ Conf FIE*. 2015;2015-February(February):1-8. doi:10.1109/FIE.2014.7044372

Emily McCabe

Emily McCabe is a master's student in the Department of Mechanical Engineering at Mississippi State University. She obtained her B.S. in Biological Engineering from Mississippi State University in May of 2019. Her research interests include medical device design and in K-12 engineering outreach culture in the university setting.

Morgan Green

Morgan Green is an Instructor in the Mechanical Engineering Department at Mississippi State University. She obtained her B.S. and M.S. in Mechanical Engineering from Mississippi State University in 2017 and 2019, respectively and is currently pursuing a PhD in Engineering Education. Her research is in the development and assessment of professional skills in engineering students, K-12 outreach, and hands-on learning.