An Effective Model for Leveraging Field Trips to Broaden Participation in STEM (Work in Progress)

Mrs. Claire Duggan, Northeastern University

Claire Duggan has a B.S. in political science from the University of Massachusetts and a M.P.A. in public administration from Northeastern University. She was appointed 2003-present Director for Programs and Operations, the Center for STEM Northeastern University; 1989-2003 Associate Director, CESAME/The Center for the Enhancement of Science and Mathematics Education, Northeastern University, and K-12 Outreach Coordinator, CenSSIS/ALERT, Northeastern University; and 1981-1989 Associate Director for Finance and Administration, Center for Electromagnetics Research (CER), Northeastern University. Publications/Papers: Reenergizing and Reengaging Students Interest through CAPSULE; A Novel and Evolutionary Method on Educating Teachers to Promote STEM Careers Jessica Chin, Abe Zeid, Claire Duggan, Sagar Kamarthi (IEEE ISEC 2011); and "Implementing the Capstone Experience Concept for Teacher Professional Development" Jessica Chin, Abe Zeid, Claire Duggan, Sagar Kamarthi (ASEE 2011). Relevant Presentations: "K-12 Partnerships" (Department of Homeland Security/Centers of Excellence Annual Meeting 2009); "Building and Sustaining K-12 Educational Partnerships" (NSF ERC 2007 - 2010 National Meetings); "Research Experience for Teachers: Integrating Research Skills into the classroom" (UNH 2nd Annual Nanotechnology Conference for Teachers April 2006); and "Educational Outreach Programs" (2005 MA STEM Summit). She was Co-principal Investigator/Program Director, Research Experience for Teachers (RET), development and implementation of the Research Experience for Teachers site at Northeastern University; Executive Director/Founder, Young Scholars Program, development and implementation of the Young Scholars Program, a summer research program for high school students; Co-executive Director, Exxon Mobil Bernard Harris Summer Science Camp, development and implementation of a residential camp for middle school students; Liaison, StepUP Imitative, coordinate Northeastern University's involvement with the StepUP initiative, a partnership effort between five universities and eleven Boston Public Schools; Project Director, IMPACT New England: A Regional Curriculum Implementation Effort, coordinated program development and implementation; Seminar Leader, Northeastern University School of Education, facilitated a group of students participating in the Introduction to Education course; Project Support Liaison, Teacher Innovation program, provided support to teachers/schools in the development and implementation of Teacher Innovation Programs (TIP), provided technical assistance to teachers through the proposal process, conducted proposal-writing workshops; Co-facilitator (2004), Boston East Pipeline Network; and Alumni, Lead Boston 2004 (The National Conference for Community and Justice). She won the 2006 Northeastern University Aspiration Award, and was recognized at the 2003 Northeastern University Reception honoring Principal Investigators that obtained funding in excess of $1 million over a five-year period.

Mrs. Jennifer Ocif Love, Northeastern University

Jennifer Love is a full-time faculty member of Northeastern University's First Year Engineering Program in the College of Engineering. She is currently working toward a doctorate in education at Northeastern University with her research focusing on preK-20 engineering education.

Mr. Nicolas Leo Fuchs, Center for STEM Education

Nicolas Fuchs currently is the Program Implementation Coordinator for the Center for STEM Education (CfSE) at Northeastern, coordinating existing and creating new outreach programs and efforts that expose K-12 students to STEM and Northeastern students to STEM outreach. He has extensive teaching experience; he is currently finishing his Master of Arts in Teaching degree (2020) and in his current role at CfSE, he teaches STEM activities to K-8 students at local schools, public libraries, and at Northeastern. In addition, he has taught robotics, physics, and fourth grade general education.

Ms. Emily Chernich
Ms. Brittany Fung, Center for STEM Education at Northeastern University

I am a student at Northeastern University pursuing a doctorate degree in Physical Therapy. I have been working with the Center for STEM Education as a part-time staff member since September 2015. I have been a part of the field trip program since then and I have seen it grow tremendously in the past few years.

An Effective Model for Leveraging Field Trips to Broaden Participation in STEM: The Energy Example (Work in Progress)

Current and emerging research cites the need for early and sustained engagement in science and engineering learning to attract young learners to STEM careers. The STEM workforce size and demographics is a national concern in the United States [1]. Federal funding agencies such as NSF, NIH, the Department of Education and educators nationwide have been focusing on solving this national problem [2]. Attracting more underrepresented students to STEM fields has been recognized as crucial to addressing the current and expanding needs of our national STEM workforce.

Field trips to local universities are one vehicle to introduce youth to STEM topics. If designed and utilized effectively, these experiences can be leveraged to encourage pre, during, and post engagement in STEM learning. With over 10 years of experience, Northeastern University has designed and implemented an effective and successful model of one-day field trips to an urban university campus. The model focuses on elementary and early middle school students, accompanied by their teachers and additional volunteers. Once on campus, the learning experience is led by University staff and undergraduate students who gain valuable experience interacting with children, communicating science and engineering concepts in addition to serving as role models for program participants. The model continues to evolve to maximize impacts of these one-day STEM experiences for all.

This Work In Progress paper will discuss the essential elements of one-day STEM field trips: the logistics, the daily program and schedule, the process from start to finish, and student and teacher feedback. The paper will also share preliminary results, analysis, discussion and conclusions.

Introduction

Field Trips provide K-12 students with the opportunity to engage in experiences outside of the classroom. Field trips were defined by Krepel and Duval as an educational experience during which students might directly engage with materials and/or content "in their functional setting" [3]. The experience generally cannot be duplicated within the classroom. Field trips should not be utilized and/or designed as a short-term teaching opportunity, but rather serve as a springboard for student interest [4] and reflection. Research suggests that a well-designed field trip experience may in fact be remembered by students well after the experience took place [5]. In engineering education, established research on the standards for preparation and professional development for teachers of engineering recommend that teachers improve their pedagogical content knowledge by engaging in STEM field trip partner programs with engineering mentors at local companies and universities [6].

Program Details

Northeastern University's Center for STEM Education offers STEM Field Trip experiences for 4^{th} to 8^{th} grade students throughout the collegiate academic year. The program launched over 10 years ago in collaboration with a National Science Foundation GK12 grant and is sustained through the active engagement of over 75 volunteer undergraduate and graduate students and student organizations per year. Now reaching over 1,200 K-12 students annually, this institutionalized program has become a highly sought-after annual experience for Boston and other local school districts. Demographics for 4^{th} – 8^{th} grade students who attended field trips in 2019 are shown in Figure 1.

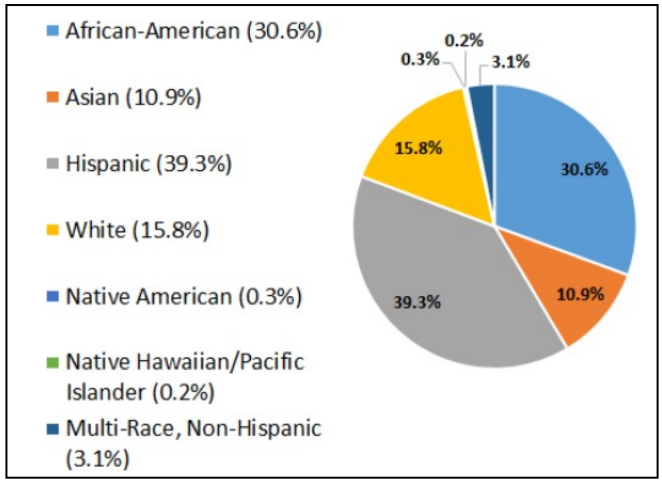

Figure 1. Demographics of field trip students in 2019 (n=1,200).

To initiate planning and reservation of a STEM Field Trip, teachers indicate their interest and desired date(s) through the Center's website. They are instructed to prioritize topics in which they would like to engage their students. Most current offerings introduce engineering and the design process in addition to offering a wide range of science and engineering activities aligned with national science and engineering standards and practices. Lessons may be drawn from resources in TeachEngineering.org [7] and/or informed by curriculum such as the Boston Museum of Science's Engineering is Elementary (EiE) [8]. In addition, each field trip introduces K-12 participants to a faculty member and/or student directly engaged in research in the selected area. Volunteers share their academic journey into a STEM major and provide an opportunity for program participants to ask questions about science and engineering but also about college.

Each field trip spans a typical school day with about 60 students arriving on busses from their respective schools in the morning (Table 1). Current offerings include: Introduction to Engineering and the Design Process (Catapults and Egg Drop); Paper Rockets; Wind Turbines; Solar Energy; Snap Circuits; Oil Spill; Water Filters; Overfishing and Sustainability; and Natural Disasters and Climate Change.

Table 1. Typical schedule for a STEM Field Trip*

Time	Activity
9:30am	Arrival
9:30am – 10:00am	Welcome & Introduction
10:00am – 11:30am	Activity 1
11:30am – 12:00pm	Lunch
12:00pm – 1:30pm	Activity 2
1:30pm – 1:45pm	Wrap Up & Depart

*no transition time between activities since all activities are in same room.

Teachers are encouraged to select a topic that will either introduce lessons they plan to cover in the classroom and/or perhaps serve as a culminating experience for their students' learning. For example, Energy is introduced in local schools in Grade 4 and typical classroom curricula covers: Matter and Energy, Technology/Engineering and Engineering Design [9].

According to the state curriculum frameworks, the overview for Grade 4: Matter and Energy states:

"*In grade 4, students observe and interpret patterns related to the transfer of matter and energy on Earth, in physical interactions, and in organisms. Students learn about energy—its motion, transfer, and conversion—in different physical contexts….*" [10]

In terms of engineering, technology and applications of science, the same state curriculum frameworks include this 4th grade standard: "*4.3-5-ETS1-3. Plan and carry out tests of one or more design features of a given model or prototype in which variables are controlled and failure points are considered to identify which features need to be improved. Apply the results of tests to redesign a model or prototype.**" where * indicates engineering design. [11]

Teachers are asked to select two activities. A general engineering activity is often coupled with a content-specific offering. One teacher, for example, might select catapults to provide a framework for the engineering design process paired with a wind turbine activity. Another teacher might have covered engineering and the design process in the classroom and select two energy related activities such as snap circuits and solar panels. The remainder of the paper describes the Wind Turbine (Energy) field trip in more details, as a typical example of this field trip program.

Overview of Wind Turbine Field Trip

This activity provides participants with an introduction to the sources of renewable energy, primarily focusing on wind power. The introductory presentation provides a review of engineering and the design process [8], discusses how a wind turbine works [12] in addition to outlining the benefits and the consequences of building wind turbines in our region. Students then engage in a design activity, building their own wind turbines. In small groups of two to four students, they create cardboard blades to maximize the efficiency of their turbines. The blades are then fit to the wind turbine, driven by a household box fan, and either generate electricity via a direct current (DC) motor or perform work by lifting a weight (box of crayons) via a drive shaft (Figure 2).

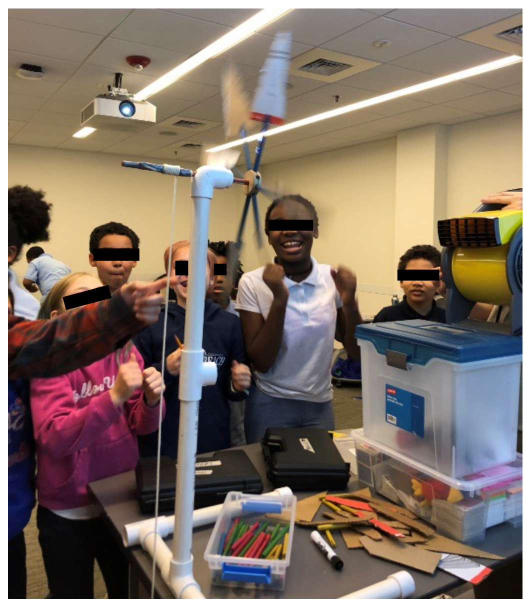

Figure 2. Students testing cardboard wind turbine blade designs.

Both options can be used to calculate energy (watts) generated by the students' blades and the speed that the turbine generates mechanical energy. By adjusting the size (area) of the blades, the shape, angle, and length of arm (radius), students can analyze which designs work more efficiently. Students design their turbines with the engineering design process in mind. They brainstorm their ideas and make decisions based on observation and analysis. Students redesign and modify their existing blades to increase efficiency. This activity has a variable range of intricacy levels and can be conducted very effectively with any age range of students.

The Wind Turbine activities are designed to enable students to:

1. Understand what engineers do and why engineering is important.
2. Identify and use the steps of the engineering design process.
3. Understand how and why wind turbines offer a popular source of renewable energy.
4. Identify arguments against the construction of wind turbines.
5. Construct a model wind turbine and refine the design based on testing and iterative designs.

Welcome & Introduction (30 minutes): Students are given a brief overview on engineering – the different engineering disciplines, what engineers do, why their work is important, a quick review of the engineering design process and how engineers apply it. A Prezi presentation covers energy, mechanical and electrical energy, the history of wind power and it uses, *The Boy Who Harnessed the Wind* book [13], wind turbine installations in the United States, mechanics of wind turbines, and an introduction to a university wind energy engineering professor.

Wind Turbine Activity 1: Mini Lesson (15 minutes)
Introduce Activity 1 by explaining that students will be making their own wind turbines. Present the engineering design process, emphasizing the use of the scientific method. Discuss what makes a successful wind turbine design. Remind students to consider the number of blades and shape of blades in their design and discuss why students think each of these factors is important and how it would contribute to effective wind turbine performance.

Wind Turbine Activity 1: Active Engagement (30 minutes)
Break students up into groups of 4 – 5 and give each group a set of materials. Students are given time to discuss their blade designs and draw them out on sample paper-pieces of cardboard before they are given scissors to make their blades. Each group constructs 2 turbines – one high-energy (DC motor) and one high-power (lifting), using as many or few blades they think will work best.

Wind Turbine Activity 1: Testing and Calculations (15 minutes)
After design is complete, each group tests both turbines simultaneously to save time in front of box fans. Students use stopwatches and multimeters to measure lifting time and output current, respectively. Measurements are recorded on the whiteboard and on the students' hand-outs. Students complete calculations to determine the power and energy of each turbine.

Wind Turbine Activity 1: Assessment (5 minutes)
During and after the testing, students are asked to self-assess their turbines. Why did some designs work or not work particularly well? What things did students think would work but did not? Why?

Wind Turbine Activity 1: Re-Engagement (20 minutes)
Students are given the opportunity to redesign their windmills based on their initial test. They are reminded that engineering is a process of refining ideas and designs based on results of testing, and that making adjustments and learning from testing allows products to be improved.

Wind Turbine Activity 1: Closing (5 minutes)
After re-designs and retesting are concluded, students are brought back together for a final self-assessment. What did they improve on their designs? What did they learn? Teachers are provided feedback sheets for continued discussion and reflection upon return to the classroom.

Assessments and Results

Feedback from students and teachers as well as volunteers at each field trip is critical and is gathered in two structured ways. Teachers and volunteers complete informal "Exit Tickets" about their experiences that day. This immediate feedback asks about overall reactions, positives and suggestions for the field trip. A longer teacher feedback form and student feedback forms are then sent back with the school and asked to be returned for a deeper understanding and quantification of the field trip impact. The forms also act as a follow-up point of contact with the classroom afterward. Areas assessed are instruction, curriculum, organization, and relevance. Highlights are also shared with school and district leaders through Blog posts of each event.

In 2019, 100% of teachers who participated in a field trip responded that they would recommend a STEM field trip to colleagues and would be interested in coming again. When asked about whether they would recommend continued discussion in their classrooms after the field trip, 71% of teachers responded 'yes'. 75% of teachers indicated that the field trip introduced a new topic to their students while 25% said that the field trip reinforced a topic previously taught. 62% of teachers indicated that the field trip provided new information on a topic that they did not teach. 50% of teachers indicated that the field trip supported an existing topic in some way. 12% of teachers said that the field trip served as a wrap-up activity to a recent lesson in their classroom.

In their survey responses, teachers elaborated with specific references to discussing the field trip directly with their students back at school, discussing STEM topics in general, and discussing college and STEM career awareness. One teacher commented: "*The energy and excitement in the room was contagious. Children across our grade stepped up to the challenges and encouraged each other. A few of the students chatted about attending a college similar to Northeastern University!".*

Students provided their own feedback and upon subsequent analysis, several themes emerged including self-efficacy, fun, friendship and an awareness that engineering benefits society:

"I liked the wind turbine activity because I felt like a scientist."

"I liked the windmill because it was a really cool experiment."

"I liked making the windmills with my friends."

"I liked the windmills because it makes energy for cities and countries."

Discussion and Conclusions

Although Northeastern University's Center for STEM Education has been offering STEM field trips for the past 10 years at no cost to schools, feedback and survey instruments were recently modified to study subsequent impact. Data collected from teachers and students in 2019, including wind turbine field trips in Fall 2019, have continued to support evidence that students' interest in STEM topics continues beyond the day of the field trip. In fact, many of the teachers who bring their students to NU STEM field trips have been coming back each year for several years. What distinguishes NU STEM field trips from other science field trip offerings in the area is an integrated experience with engineering. Given the popularity of these field trips and the diverse range of topics that teachers can choose from, additional data from students and teachers will continue to be collected in future academic years.

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