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Comparing What 8th vs. 10th Grade Students Take Away from Engineering Curricula Incorporated into their Physical Science Classroom

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Comparing what 8th vs 10th grade students take away from engineering curriculum incorporated into their Physical Science Classroom- (Work in Progress)

Background and Motivation

Engaging students through hands on activities, projects and inquiry based instruction can be an effective way to introduce engineering and engineering careers to high school students. When students investigate and learn about these topics through an extended design project, it could increase their overall interest in engineering or science subjects[1]. The National Science Foundation Graduate STEM Fellows in K-12 Education program at Drexel University partners with the School District of Philadelphia to create a year-long fellow- teacher pair and places university graduate students within the classroom during the school year to introduce engineering concepts to high school students. Graduate students within engineering disciplines are paired with a high school teacher to develop and administer activities that focus on a single theme. Using this approach, fellows are able to introduce and work with students on extended projects and activities throughout the year.

Incorporating engineering curriculum into the classroom can be an engaging way to show high school students what engineers do and what types of problems engineers face[2,3]. Furthermore, by allowing a graduate engineering fellow to work closely with the high school teacher to administer these projects, students have a better perception of engineering following the activities[4-6]. The Graduate fellow can tailor material and create projects that directly utilize the information that students are learning within their science curriculum and offer an additional experiment for the students to learn from. It also allows the fellow to build on engineering ideas and themes to introduce many topics and disciplines throughout the school year. This is advantageous because it can strengthen the students' overall knowledge level and give them a better idea if they would like to pursue this career field.

As a point of motivation for this design project, the main theme for introducing classroom content is designed around the National Academy of Engineering's Grand Challenges. A visit to the Grand Challenge website lists four overall themes that the challenges focus on: health, joy of living, sustainability and security. The challenges are composed of a list of 14 topics that include "Improve and Restore Urban Infrastructure", "Provide Access to Clean Water" and "Engineer Better Medicines" to describe global issues that future scientists and engineers can work on into the future[7]. Additionally, to make the concepts more relevant within the classroom and to create the objectives for student learning, The Next Generation Science Standards were consulted. These standards describe both science and engineering practices that students can develop over time that will increase their overall understanding of scientific principles, the work of engineers and also the link between engineering and science[8].

The motivation for this paper is to evaluate the impact of activities designed to let students explore engineering and investigate problems using an extended design project that runs throughout the school year. It was administered through the Drexel-GK-12 program, in partnership with the local Philadelphia School District. The goal is to utilize information gained

from student survey responses to evaluate how this set of activities and projects affect the overall view of engineering that students within in a physical science classroom have and to compare that between two different grade levels (8^{th} and 10^{th}). By evaluating how these students interpret the lessons, it will give useful information in understanding how to better design and integrate engineering activities within their science curriculum, and how these students interpret those engineering interactions.

Project Implementation

Project Participants and Timeline

The project was conducted over the course of the academic school year (September to June) at Girard Academic Music Program, a public magnet college preparatory school that incorporates both academic and music requirements within the curriculum. The hands-on activities, projects and lectures were designed and administered by the 9^{th} and 10^{th} grade Science Teacher and a doctoral candidate in an engineering discipline. A total of 63 students participated in the activities with 33 students in 8^{th} grade and 30 students in 10^{th} grade. 57 % of students were female, and 43% of the students were male. Students worked in groups of 3-7 people on each activity for periods of one day up to 2 weeks.

Project Description

The objective of the project was to introduce students to the various aspects of engineering and engineering design through activities and projects that relate to the topics within the physical science curriculum. The entire school year was spent reinforcing the engineering design process and grand challenge themes. Students are introduced to the Grand Challenges in hands-on activities that allow them to practice the engineering design process and think about how the challenges impact their everyday life.

Description of Activities

During each unit, students were asked to complete a task, where they had to utilize the information from their coursework to be successful in completing the task presented. Classes began with a short discussion on the topic, and then students were given time to form their own research and learning objectives. Students were given several class periods to learn about these topics by exploring the internet and using guided worksheets to help them complete their task. The graduate fellow and science teacher served the role as a consultant to help the students during the research and design process. Each activity allowed students to get more acquainted with issues that engineers face, and the overall method for how they address those issues. The activities are detailed below:

Introduction to the NAE Grand Challenges: To introduce students to the National Academy of Engineering's Grand Challenges, an internet based scavenger hunt was administered. Students worked in teams of 3-4 students to solve clues that guided their exploration of the engineering challenge themes and current news. Students were given a total of two classroom periods or a total of ~90 min to solve the clues, which served as a guided research activity.

Water Filtration Activity: During the unit on Atoms, the periodic Table and Chemical Bonding, Students were asked to apply that information in the design of water filtration devices. In the first part of the activity, students learned about the steps to purifying water and how engineers are addressing the NAE Grand challenge "Provide Access to Clean Water". Students worked in groups and were given the task of designing a system that will purify a cup of dirty water that had been contaminated with dirt and food coloring. They were given this challenge with the only instruction to clean the water. They had to set their own guidelines for clean water based on what they were learning in their science class while competing with their classmates to produce the best cup of clean water.

Spaghetti Structures Activity: During the unit on Atoms, the periodic table and chemical bonding, students were introduced to the process of Engineering Design through a small group activity. Students learned about the various steps of the engineering design process through a guided activity. Students were introduced to the concept of constraints and limitations when asked to build a tower of a specific height that could hold a certain weight. They utilized information from Physical Science in deciding what type of structure would allow them to have success in their design.

Cardboard Roadways Activity: During the unit on Force and Motion, students worked in groups of 3-5 to design a roadway that would allow a small die cast car to remain in motion for 10 seconds and not run over their track by more than 1 foot. Students were first introduced to the activity following the first few classes on force and motion, then as their knowledge in these subjects increased, given the chance to refine their design. In the first part of the activity, students performed trials to determine how different track orientations affected their car movement, while the second part of the activity relies directly on the students to apply that information in designing their tracks.

Evaluation

To evaluate the overall impact of the activities on student opinions and knowledge about engineering, a combined Likert based and free response survey was given at various points throughout the school year. Students were polled at the start of the school year, 6 months into the year, and then at the end of the school year. Individual surveys or exit passes were also administered at various times throughout the year to evaluate the impact that individual activities had on student views. All surveys were administered in a way that allowed student responses to remain confidential, while exit passes were handed out and collected at the end of class. The surveys asked students about post-high school goals (career level, career interest, likelihood to pursue a science or engineering career), knowledge about engineering or a particular engineering challenge (What does an engineer do? Name a type of engineer. What type of problems do engineers face? List a concept that you learned), and student opinions about engineering (Why do you think it is necessary to solve this grand challenge? How does this affect your academic or personal life?).

Results and Discussion

To get a baseline for student knowledge and opinion about engineering, a survey was given prior to fellow introduction into the classroom. At the start of the school year, more than half (58.3%) of the students in both 8th and 10th grade were interested in pursuing a post college degree (master's and doctoral) and 30.6% were interested in pursuing a bachelor degree while 11.3% were interested in pursuing a high school (6.5 %), associate (3.2 %) or technical (1.6%) degrees as their highest level of education. This indicates that many of the students were already thinking about their future and what type of education they want to obtain at this time. Since students are already thinking about school after high school, looking at what type of career that students are interesting pursuing would give an idea of what their baseline interest is in engineering and science fields.

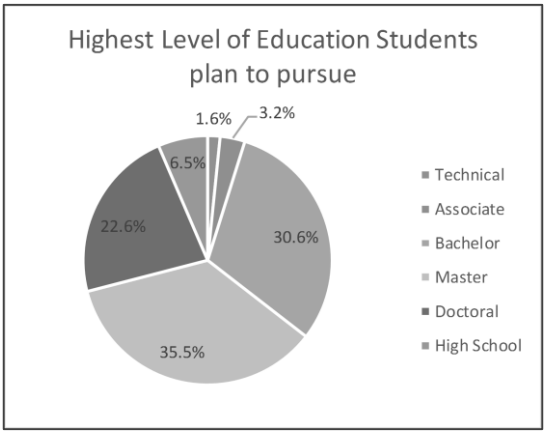

Figure 1. Student response to the question "What is the highest level of education you plan to pursue?" at the start of the year, prior to beginning any engineering activities with a graduate fellow.

Students were asked which career fields they were interested in pursuing as a top choice and the results are shown in Figure 2. More than 30% of students were interested in pursuing careers within the Arts, A/V technology and communication fields, a little over 15% were interested in Health Science, and there is an even distribution among ten other career fields.

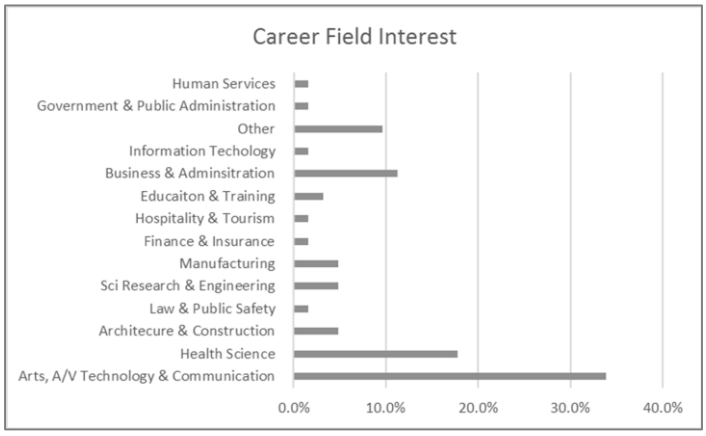

Figure 2. Student career field interest at the start of the school year. Response to question "What profession are you most interested in studying further or working in?"

In addition to asking about career field interest, students were asked whether they could see themselves as engineers (Fig 3). At the beginning of the school year, 35% of students said they were not sure, 25.8% answered No, and 38.7% of students answered yes, which could indicate interest in the profession or simply the topics that engineers work on. When asked this question during the Mid-year survey, there was an 8.6% increase in the number of students who could see themselves becoming an engineer, 17.4 % decrease in the number of students who said No and 8.8% increase in the number of students who were Not sure. When comparing the individual results between the 8th and 10th grade students, a large percentage of the increase in Yes responses is seen in the 10th grade class, while the 8th grade class had a larger increase in the Not Sure category. The change from the start of the school year to the mid-year survey could indicate that the activities do have an impact on the students. It could also indicate that students have a positive perception of engineering and have some interest despite many not making it their top choice. The responses to the question "What part of becoming an engineer interests you the most?" also indicates that students think about engineering in a positive way. Most students responded to the question despite not seeing themselves as engineers, which could indicate that lack of interest is not a reason why the students choose other career paths besides engineering as their top choice. Student responses from the question "From what I know, Engineering is boring" and "I am more interested in this class on days when the fellow is in the classroom" also indicate student interest in engineering because 73 % of students disagree with the statement that engineering is boring and 91% of students are more interested in class on days when the fellow is present.

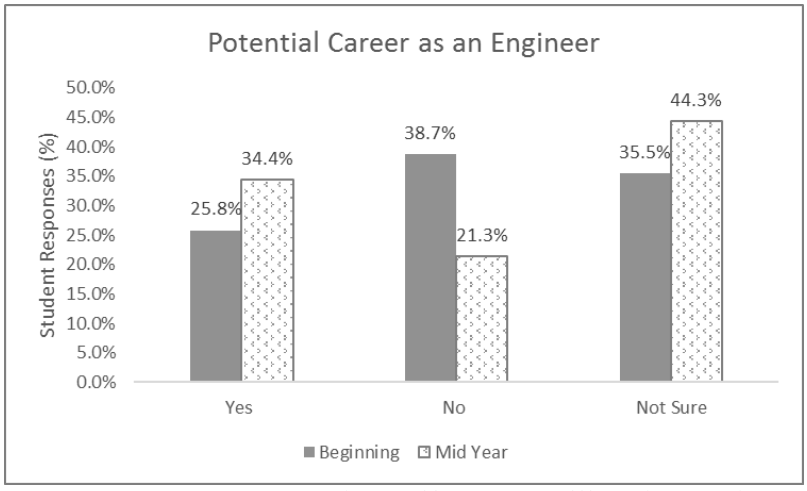

Figure 3. Student Response to the question "Could you see yourself becoming an Engineer?" at the start of the school year (Beginning), prior to beginning any engineering activities, and during the middle of the school year (Mid-Year), after 6 months of engineering activities.

Table 1. Student responses by grade for the question "Could you see yourself becoming an Engineer?"

8th			10th		
	Beginning	Mid Year		Beginning	Mid Year
Yes	27.3%	30.3%	Yes	22.6%	39.3%
No	30.3%	18.2%	No	45.2%	25.0%
Not Sure	39.4%	51.5%	Not Sure	25.8%	35.7%

There was no survey given following the introduction to the Grand Challenges, however students were polled before starting and after completing the water filtration lab. The survey asked students about the Grand Challenge "Provide Access to Clean water" and what do they think they would gain from completing this lab. The survey contained both Likert based questions scaled from 1 to 5, and free response questions. The post survey asked students to specifically mention what they learned and how that information impacts them academically and personally. When looking at the results, the scores were summed to determine the percentages. While the percentages are based on a total count of students in each grade.

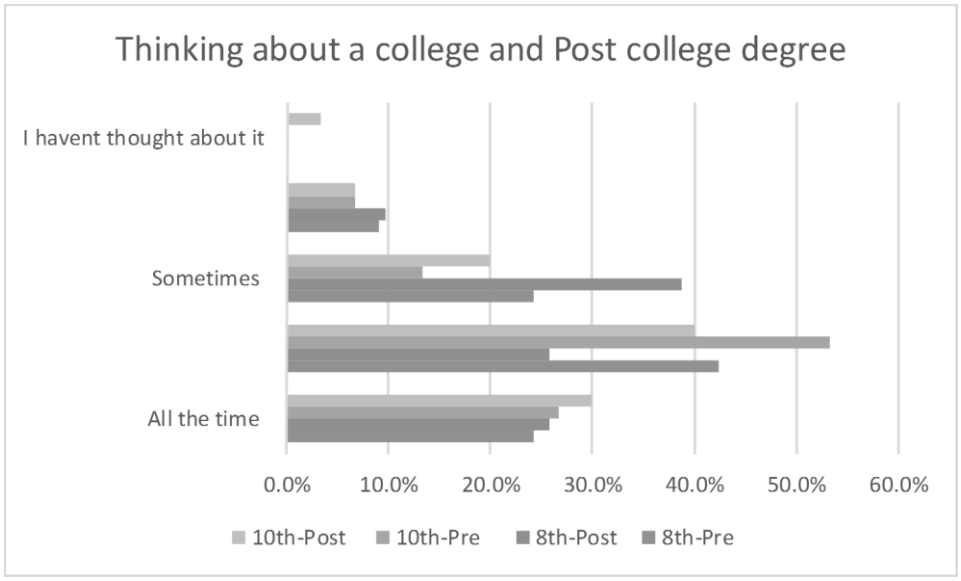

Figure 4. Student Response to the question "How often do you think about College and a post college degree?" prior to completing (pre) and after finishing (post) the Water Filtration Lab.

An initial analysis of the survey responses reveals no differences in the data between 8th and 10th grade students, when looking at whether they think about a college or post college degree or their likelihood of pursuing an engineering degree (Figs 4& 5). When thinking about a post college degree, 24% of the 8th grade and 27% of the 10th grade students think about these degrees all the time. When looking at the likelihood of pursuing an engineering degree, 20% of 10th grade and 21% of the 8th grade students said this was likely (sum of likely and very likely percentage). When looking at student likelihood to pursue a science degree however, the number of students in the 10th grade who answered likely is nearly twice the number of students in the 8th grade (Fig 6). A total of 27% of 10th grade students would likely pursue a science degree while that number was 15% with 8th grade students. The results show little changes following the post survey, however it was noted that there was a slight increase in the number of students who were likely to pursue a career in science for the 8th grade (from 15% to 22%) and a decrease in the number of students who were Not likely to pursue engineering (from 34% to 20 %).

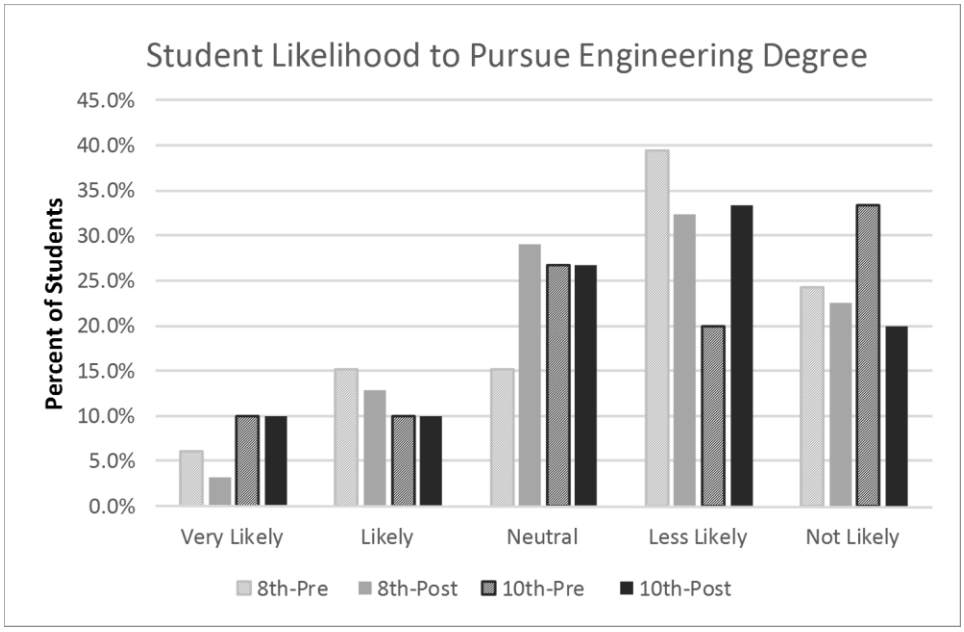

Figure 5. Student Response to the question "How likely are you to pursue a college degree in Engineering?" prior to completing (pre) and after finishing (post) the Water Filtration Lab.

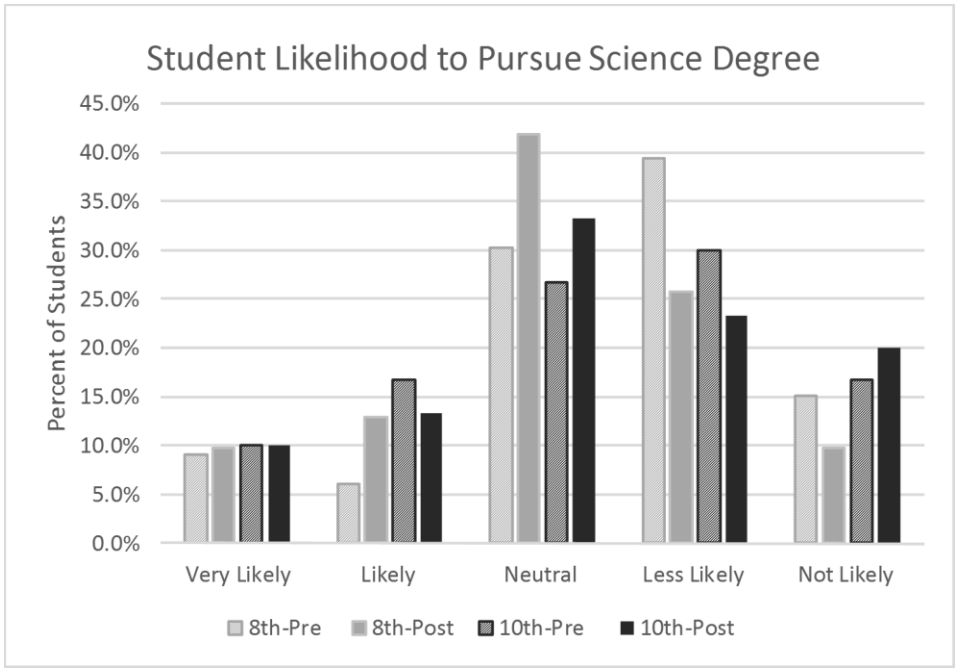

Figure 6. Student Response to the question "How likely are you to pursue a college degree in Science?" prior to completing (pre) and after finishing (post) the Water Filtration Lab.

An initial review of the free response results from the water filtration lab, show that students did learn something and talked about how the grand challenge affected them in some way. Nearly

all of the students could list three things that they learned and how the challenge affected them. Students responses noted the impact that the lab had on them academically as:

- *"I learned how to clean dirty water and make it safe to drink."*
- *"How to work in groups with people you may not normally work with in school"*
- *"In academics, I learned how different chemicals affect dirty water."*
- *"I got a lot better with working in a team. I tend to try and do everything but in this we all helped each other and put our input in on things."*

Below are some of student responses for what students got out the lab in terms of their personal life:

- "*In my personal life this lab has taught me how to check my water and make sure its clean not only for me but for anyone who drinks water that is found in my house."*
- *"This lab got me thinking about this and many other issues in the world that need to be solved. It also started some interesting discussions at home."*
- *"A realization in how much water we use in a day, and the processes we take in filtering and cleaning water in our urban environment."*
- *"In terms of my personal life it made me understand how much engineers really do for us and how they save lives."*

Student responses to this question indicate that this lab had a positive impact on the students both academically and personally. In general, more students noted that they felt that they gained something from the lab in terms of their academic and personal life. The differences in the interest to pursue a college degree in either discipline may be related to how each of the groups viewed and approached the lab activity. It is also important to note that the students were only introduced to problems that engineers face, and no real process for how to approach the problem was given. Therefore, students may have approached the problem differently either purely looking at the science that needed to be done to clean water, or creating a device that will go through all the steps needed to clean the water. These results do indicate that further examination of engineering may have a positive impact on student's likelihood to pursue an engineering or science degree as more engineering concepts and chances to practice those concepts are introduced.

Conclusion

The project is on-going and therefore only a preliminary evaluation is possible. The results presented in this paper only comprise of the results from the Likert based questions about interest in engineering and science, careers fields and first few activities for the project. These preliminary findings suggest that the project activities are increasing student interest in engineering and engagement in the classroom. The results from the free responses have been viewed however a more in depth analysis of those results are underway and will be taken into account at a later time. Once all the activities for the project are completed an analysis will be conducted to look at the impact the project had on student knowledge about engineering, as well

as how students feel the information has made an impact on them, in their academic classwork or career goals and personally in their life outside of school.

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