“Who Wants to Be a Bioengineer?” A Study of Biotechnology on Student Learning Gains and Interest in Pursuing Science Careers in Middle School Science Classes

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Abstract

Early exposure to STEM supports students' critical thinking and reasoning skills and improves academic learning gains (National Research Council, 2011). The purpose of this action research project is to analyze the impact of introducing middle school students to biotechnology. Early interventions should promote a positive attitude towards science in general, increase content knowledge and the desire to pursue a science related field of study. The focus of this action research will be to use a combination of real-world case studies, lecture notes and inquiry based laboratory activities to expose middle school student to biomedical and biotechnical careers. The control group of students will only receive the pre- and post- interest surveys and assessments. The experimental group will receive in addition to the surveys and assessments interventions that include 'Pipetting by Design', select Pompe disease lessons, and a biomedical engineering lab activity on 'Designing Protective Drug Coating.' The assessments will be used to evaluate student content knowledge gains. Student affinity towards biotech careers will be assessed through incorporating pre- and post- picture surveys of 'what is an engineer?'. I will collect qualitative data to measure significance where appropriate. These lessons were demonstrated by the Bench to Bedside Institute at the University of Florida.

Key words: biomedicine, biotechnology, Pompe disease, STEM, TBL, interest survey

Rationale:

Science, technology, engineering and mathematics (STEM) is at the focal point of our current governing body. President Obama has encouraged congress to support hiring more STEM teachers and funding STEM related programs to help bridge the gap in our students being prepared for future STEM related jobs. More and more schools are jumping on the band-wagon of becoming a STEM school or offering STEM programs in hopes of higher cognitive thinking students and better state/federal test scores. STEM careers drive our global economy in generating innovative ideas, products and companies that support the demands of the growing populous. However, the supply and availability for STEM ready workers will not currently or in the near future meet that demand unless something is done to improve students selecting STEM careers. Over the past ten years, STEM job growth tripled that of non-STEM jobs. (http://www.esa.doc.gov/reports/stem-good-jobs-now-and-future) With this growth at a rate of 17% from 2008 - 2018, STEM workers will see less joblessness that continues to plague non-STEM workers.

Making the switch to support STEM is more of a slippery slope than a smooth transition. Many teachers in these lower grades are generalist in their educational training. Many K-8 teachers are ill prepared or intimidated by the thought of teaching outside their comfort zone. Research suggests the need to expose children to appropriate STEM opportunities early in their education (Bagiati et al., 2010). The natural progression of STEM related classes will grow from the science and math curricula. What better way to improve early exposure to STEM then through introducing students to biotechnology? Humans have embarked on enhancing their life-style for centuries using biotechnology. This has been witnessed in bioengineering techniques such as artificial selection for desired animal and plant species, sewage cleanups and oil spill (https://www.plt.org/biotechnology). Factors that restrict the teaching of biotechnology include; a lack of expertise by teachers in the content area; a lack of experience in appropriate learning activities; a scarcity of resources and curriculum materials; and insufficient teaching time (Dawson and Schibeci, 2003). With STEM jobs holding critical components of sustainability in our local and global commerce, what will drive our classroom teachers to act? Accessibility and training! This contribution for professional advancement was achieved by the UF Bench to Bedside 2016 summer program.

Attitude is how we think or feel about something. The attitude students take with regards to their learning can positively or negatively affect how well they achieve their learning objectives. Students with a positive disposition concerning scientific concepts and learning general outperform students with negative outlook. Many students have a negative attitude towards science in general. This may be due to the lack of early exposure to concepts with relevance to real-world connections. The more actively engaged students are with their science studies, the more likely they will see it as fun and start to enjoy learning. This positive feeling may contribute to a positive attitude towards science subjects and even selecting a science career down the line.

I teach middle school science at a Title I school in South Florida. The curriculum we have adopted is IQWST (Investigating and Questing our World through Science and Technology) and offers interactive hands-on inquiry science lessons in the four major content areas; Chemistry, Physical Science, Earth and Life Science. My demographics of students varies from ESE to Advance with a heavy emphasis on ELL students. My school also has over 89% of its 1600 students on free or reduced lunch. During the Life unit, I introduce the students to the central dogma leading up to Mendelian Genetics. As time permits, I broch the subject of mutations and technological advances in therapies.

Given that our educational system is highly standardized state test oriented, many students are robed the rich content knowledge of science education in the field of biotechnology. This subject is not introduced until later in the students' education pathway nearing the end of high school. By that time, the interest in pursuing a career in this field is whining. The general attitude students come into my class with is that of dislike or distrust of the processes that constitute science. Students will profess to not ‘liking’ science while at the same time not being able to fully describe the various fields that science plays a role in.

Biotechnology plays in intricate role in all our lives as it is the basis for present and future medicine. Biotechnology is how our lives are forever changed and how we are able to effectively meet the growing needs of the population when devastating outbreaks such as Ebola or Zika viruses happen. Cures for crippling diseases are within our grasp if we are producing well educated students who ultimately select to pursue a career in science, particularly biotechnology. Many students do not understand the connection between this field of study and the products that affect our society.

I often wonder if students have similar misconceptions as to what is a ‘biomedical engineer?’ With the newly found push toward STEM activities, biotechnology is slowly finding its way back into the classroom and curriculum. Despite the increase in STEM or STEAM centered classroom activities, students’ attitudes and interests are not peaked for these fields or careers. I feel that the corralling towards STEM careers must start earlier than high school and even middle school. How can we improve the attitude positively towards science and biotechnology in middle school aged students? How can we improve science content knowledge retention? Can we guide students to see themselves as biomedical engineers?

Due to the many misconceptions and negative attitudes of students surrounding biotechnology, biomedicine and the science curriculum in general, I have developed a lesson plan that will peak the interest of what constitutes a biomedical engineer and the hands-on activity will provide a novel experience for students as they explore the beginning of ‘new’ beginnings in science lead careers. With fears alleviated, students can make better informed decisions that will ultimately affect society as a whole. The focus of this action research will be to measure student interest and understanding of biomedical engineers and content knowledge gains and retention.

Intervention:

I plan to introduce biotechnology components in my curriculum this year. I will administer the pre- interest survey and science content assessment to the control group (two classes approximately 50-60 students equal to academic status as the experimental group) as well as the experimental group (two classes approximately 50-60 students). I will assess student understanding of science content by teacher-generated tests. The experimental group will receive the intervention. I plan to introduce select lessons of relevant science content showing real-world scenarios from the "Pompe Predicament How a Community of Scientists and Patients are Fighting for a Cure" UF CPET (University of Florida Center For Pre-Collegiate Education & Training), Updated 6/13/13 copyright 2013 University of Florida; designated as 'selected lessons' here. Author: Julie Bokor, PhD. The lessons and teaching strategies that I will use are listed below in Table 1: Biotechnology Intervention.

I will start the intervention with a class discussion from the first selected lessons in the Pompe curriculum to include an inquiry lab called 'Pipetting by Design.' The goal of this intervention is to pique interest in their science class by paring real-world applications to classroom experiences. Students will work collaboratively in groups of four to five maximum. I will introduce the Team-Based Learning (TBL) model demonstrated by Wayne T. McCormack, PhD. They will receive an article to read for homework and then an individual or iRAT (Readiness Assessment Test) test the following day. This score will be compared to their group or tRAT score to encourage independent preparedness and corporation among their teams. Research has found that students are more responsible for personal learning gains and more engaged when team-based learning is implemented. Teams will be rewarded for their efforts. This intervention will be followed by additional Pompe lessons and discussions. I will implement other teaching strategies such as the "Jig-saw Puzzle" using Science Take-Out kits that make use of cooperative learning. This includes students performing an activity in which they determine how DNA codes for gene which in turns codes for protein that will eventually lead to a trait in an organism. Students will work cooperatively to understand how mutations happen and the possible outcomes. The intervention will conclude with the biomedicine lesson on 'Designing Protective Drug Coating.' The assessment for this activity will have the students answering short sentences and drawing a picture of what they think constitutes an engineer before and after the intervention of actually designing a protective drug coating. The students will work cooperatively to brainstorm how to design a coating for a new pill that will act as a vector to carry the newly discovered gene therapy to its proposed place in the body. This lesson, provided by Dr. Gregory Hudalla and his team, was demonstrated at the Bench to Bedside 2016 program. The control group will only answer the pre and post picture survey. I will follow this protocol and evaluate their products using team competitions. I anticipate the students will increase in their understanding of lab techniques and science content as they are working through the protocols and various lessons.

I anticipate introducing the pre-interest survey to include students' attitude towards science as a core subject and science related careers within the first two weeks of September and the pre-content assessment near the same time. The intervention will follow for the reminder of September to mid-October, 2016. The post-interest survey and content assessment will take place near the end of October.

Table 1: Biotechnology Intervention

Week	***Select Pompe Lesson***	***Lesson Summary***	***Strategies***
0	*None*	*Pre-Interest Survey and Content Assessment*	
1	Lesson #1: Looking Through a Father's Eyes	A first person story is presented to the students to hook their interest in the disease. Using a jigsaw approach, students will learn about the fundamentals of Pompe disease and share information during a whole class discussion. This activity sets the stage for further investigation of Pompe disease specifically	• Cooperative learning groups • Jigsaw reading • Think-Pair-Share • Guided reading
2	Lesson #2: The Road to Treatment	Working in groups, students will read Pompe fact cards and use text clues to sequence the events in the discovery and treatment of Pompe disease. This lesson illustrates scientific	• TBL • Time line organizer

		discovery as a collaborative effort of many individuals building on prior knowledge	
3	Students will learn how to properly use micropipettes	Using the activity called Pipetting by Design, found at: http://www.cpet.ufl.edu/wpcontent/uploads/2012/10/Pipetting-by-Designlesson-plan-6_2012.pdf	
4	Lesson #4: Science Take-Out: From DNA to Protein Structure and Function	With a commercially available kit from Science Take Out, students step through the process of translating and transcribing a DNA sequence. Using the student worksheet provided here, students then consider how the acid alpha-glucosidase gene is affected by mutations and how the change in structure affects the function of the enzyme. • Technology: Biotechnology assay kit	• Connecting to biological basic concepts • Making inferences • Inquiry investigation • Data analysis • Synthesizing information • Whole class discussion
5	Lesson 5: Putting it All Together	Students will perform a colorimetric assay on patient samples to determine percent activity of GAA. They will perform a confirmatory test by comparing the patient DNA sequence to the reference and identifying any mutations. They will transcribe sequence into mRNA and translate it to amino acids. With this sequence, students will use a set protocol to fold it into a protein. They will compare mutant and normal functioning proteins.	• Using Punnett Square to explain inheritance by genetics • Cooperating to make group proteins and • Discussing results.
6	Lesson 7: Exploring Gene Therapy	Students will learn about the benefits, dangers, and ethical dilemmas associated with gene therapy clinical trials through a web quest.	• Whole class Role play • Whole group discussion
7	Biomedicine: Drug Coating	Using PowerPoint from	

Changes to Action Research Intervention

Some changes made to the intervention are as follows; the type of content assessment, the number of students in the control and experimental group, timing of curriculum, and the use of tRAT and iRAT test following a TBL modeled with reading assignment. As the unit progressed, time became a limiting factor. Although the TBL model was not used, components of the TBL were noted. The students were required to collaborate their learning experience during the Jig-saw puzzle model. Core student groups were arranged by numbers one through four and each number was assigned a component of the four areas of study needed to have a complete understanding of the central dogma, genetics, lysosomes and enzymes. Students were then brought back into their home or core group to discuss and share out compartmental learning. Only through working together and sharing information could the core groups answer the follow questions to that lesson. The advantage of the iRAT and tRAT would be to prove to the students that collaborative learning scores better over individual learning. This strategy was not essential in the overall goal or focus of this report. The overall size of this action research plan was reduced. Initially, there was going to be approximately two classes each for the control group and the experimental group. The number of students was reduced to one class in each group. The sheer amount of data versus the one lone person wading through the potential data overload was the determine factor. The timing of the action research plan was also changed. Initially, it was intended to be introduced early in the school year. Due to changes in the introduction of life science, this action plan was staved off till after the students returned from winter's break. The final change to this action plan involved the type of content assessment. Previously mentioned, a pre- and post- summative assessment of pertinent core content was planned. However, formative assessment was ultimately used to monitor student learning of key concepts and recalling the concepts taught in the life science unit taught weeks prior to the action research plan. A quick assessment of 'thumbs up/down' allowed for content check and on the spot feedback. Students could then identify their own strengths and weaknesses and which target areas needed to work.

Connections to Bench to Bedside Summer Institute:

Many of the activities I plan to use in my curriculum are based on exposure from the 2016 Bench to Bedside Summer Institute I experienced this past summer. This new content detailing intriguing applications of biotechnology and its role in so many aspects of our lives is astonishing. The materials needed to perform these labs will be provided by the Bench to Bedside program as well. I will need to borrow equipment lockers from CPET to perform the Pompe Predicament lessons as well as the biomedicine engineering activity and all Science Take-Out activities. The topics addressed in the overarching unit will include the central dogma and Mendelian genetics. The advantages and disadvantages of mutations leading to protein and trait expression will also be addressed. The Pompe disease unit of lessons has many activities that will meet the needs of my students in understanding key concepts prior to creating a vehicle to get the newly found gene therapy to its intended place in the body. Students will hopefully walk away with a clearer ideology of what constitutes an engineer or biomedical engineer. My hope is that many will see themselves pursuing careers related to science.

Data collection and analysis:

I used both quantitative and qualitative data analysis. I collected data related to the students' attitude towards science in general. This was accomplished using a 5-point sliding scale on both the pre-and post-survey of questions ranging from strongly like to that of strongly dislike. The pre-survey will be given prior to the unit and the post at the end of the unit and/or interventions mentioned. I surveyed students' initial ideas of what an engineer was by having them draw a picture as a part of their questioner. The 'draw me a picture of an engineer' was also be given pre- and post-intervention. I analyzed students' prior and post content knowledge using selective formative assessment questions. I qualitatively compared their pre- and post- assessments and surveys.

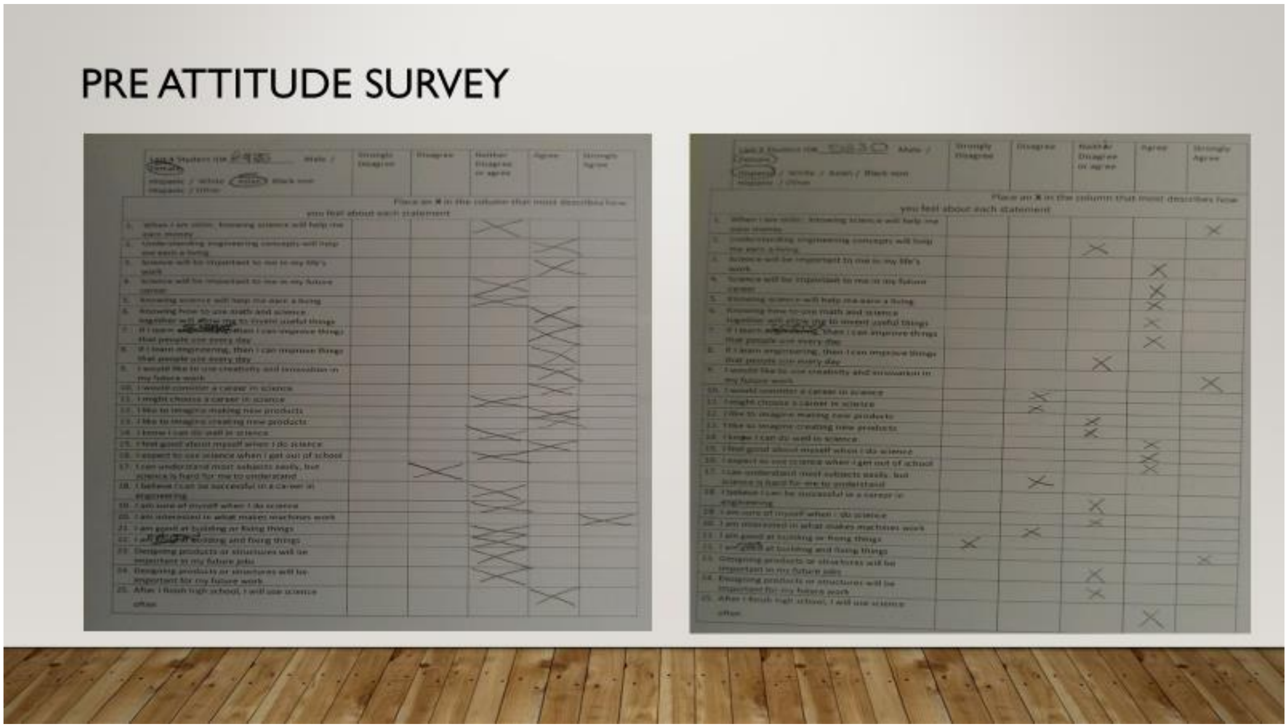


Figure 1: Examples of Pre-Attitude Survey taken by a sample of demographics of students

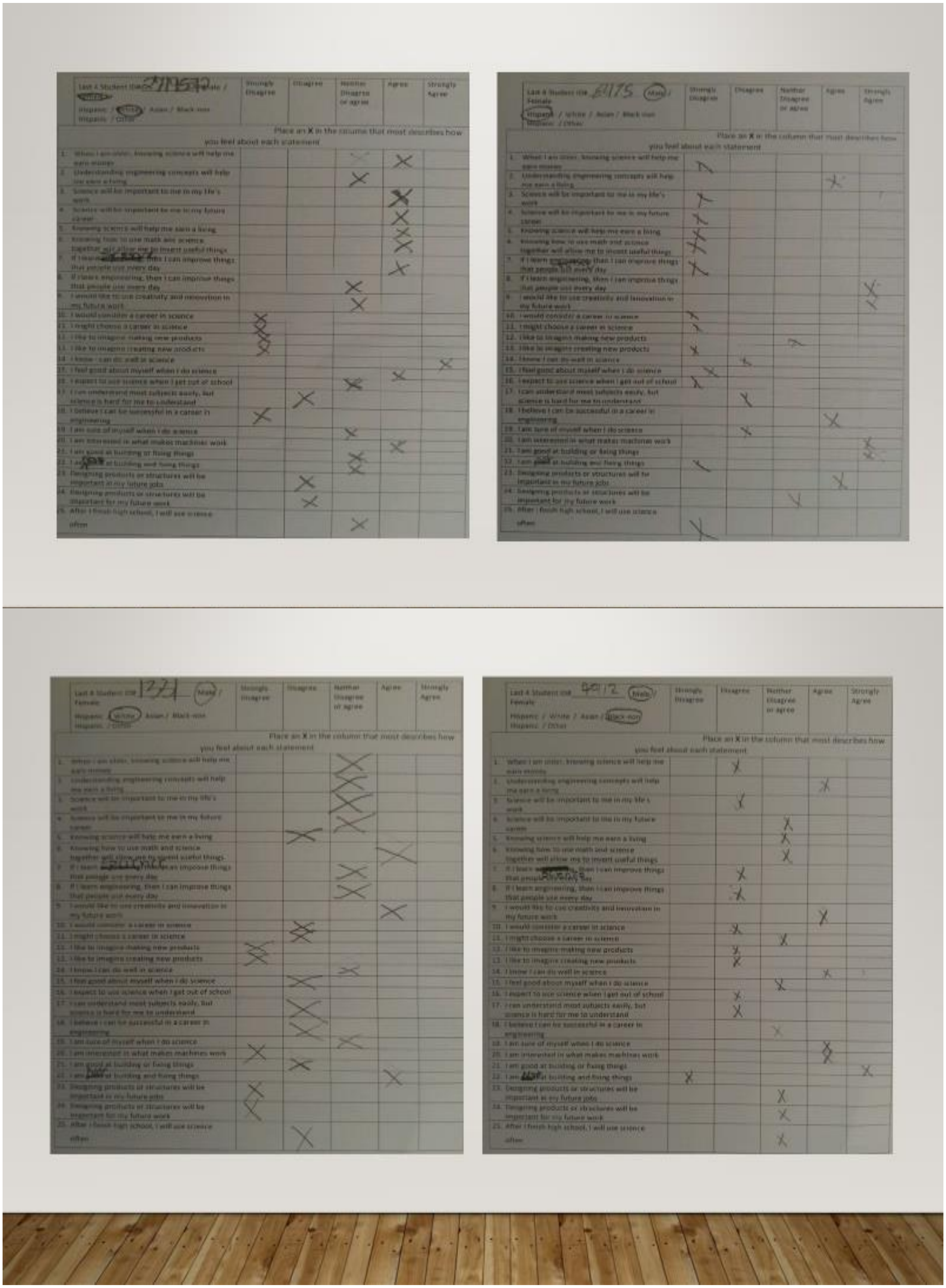
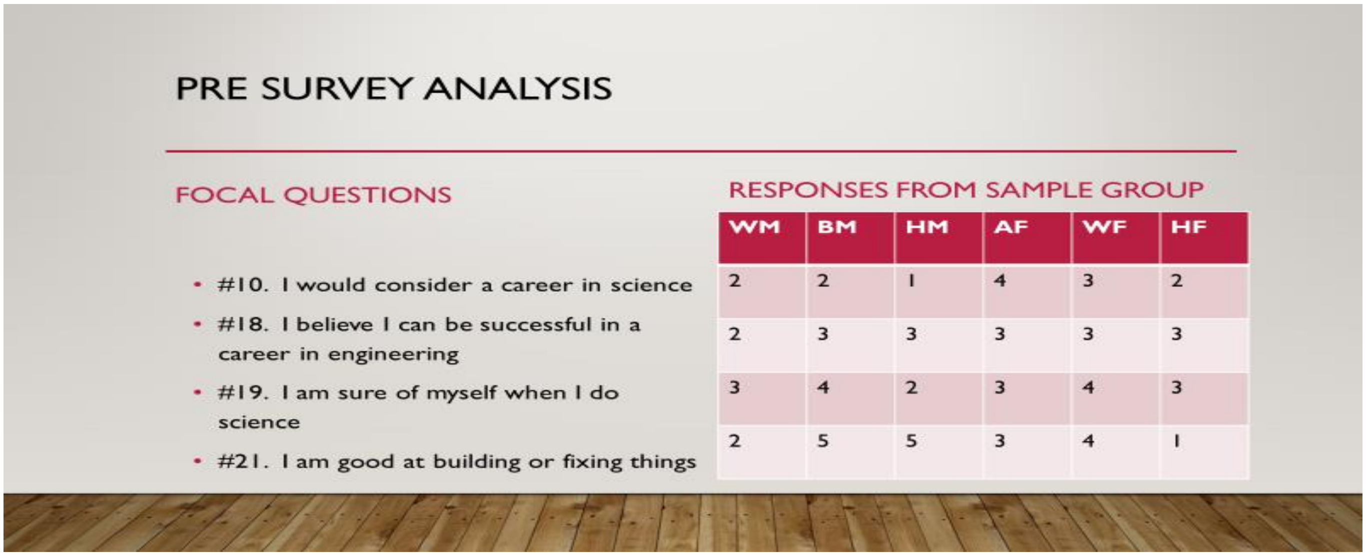


Figure 1: (continue) Examples of Pre-Attitude Survey



PRE SURVEY ANALYSIS

FOCAL QUESTIONS

- #10. I would consider a career in science
- #18. I believe I can be successful in a career in engineering
- #19. I am sure of myself when I do science
- #21. I am good at building or fixing things

RESPONSES FROM SAMPLE GROUP

	WM	BM	HM	AF	WF	HF
#10	2	2	1	4	3	2
#18	2	3	3	3	3	3
#19	3	4	2	3	4	3
#21	2	5	5	3	4	1

Figure 2: Summary of key attitude questions

Figure 3: Pre-survey Draw a Picture of an Engineer at Work

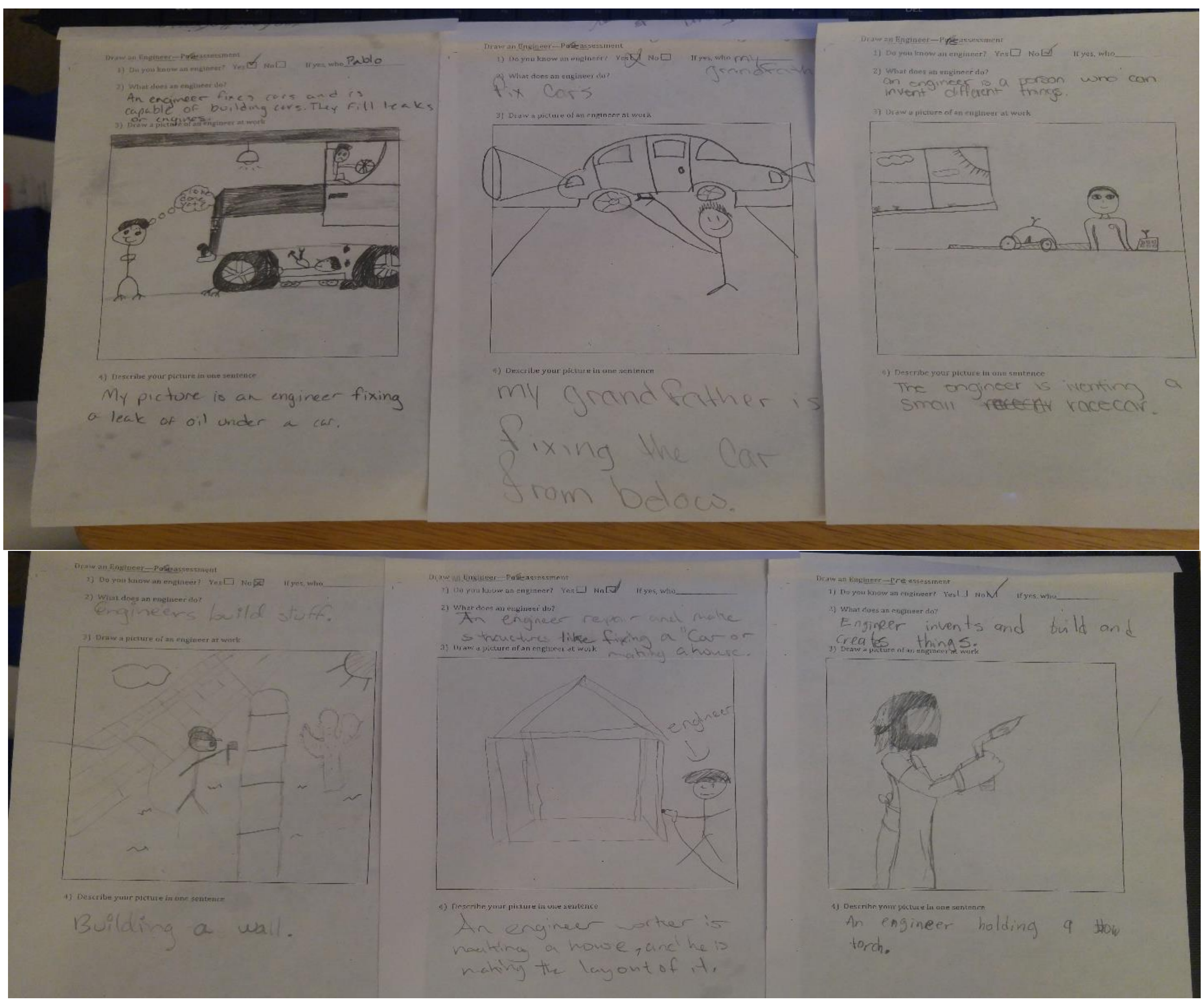
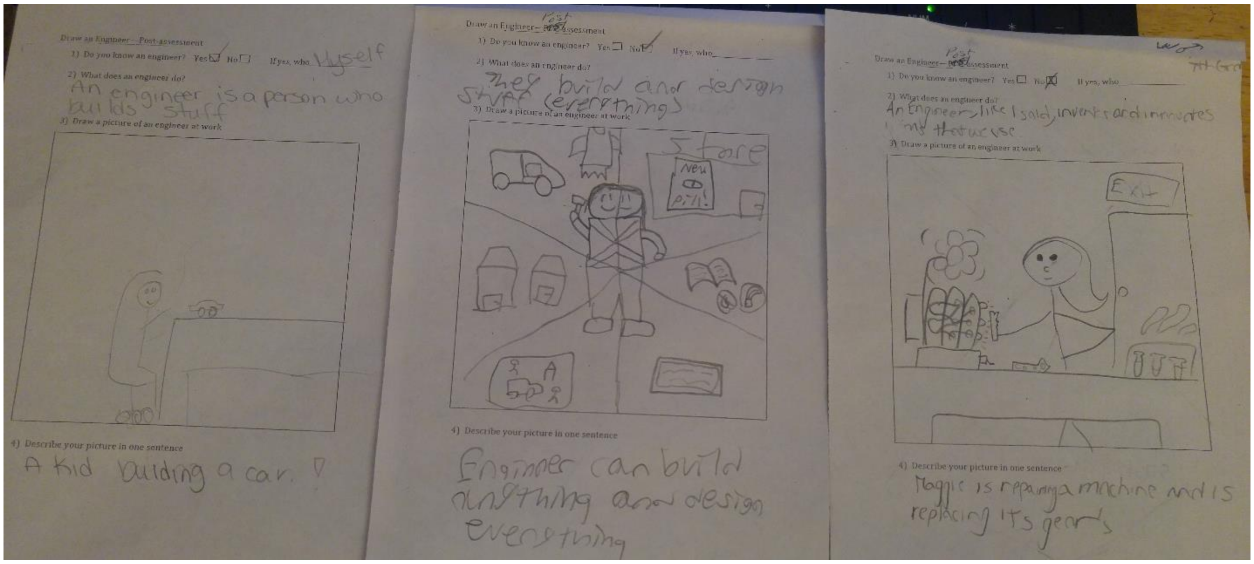


Figure 4: Post-survey Draw a Picture of an Engineer at Work



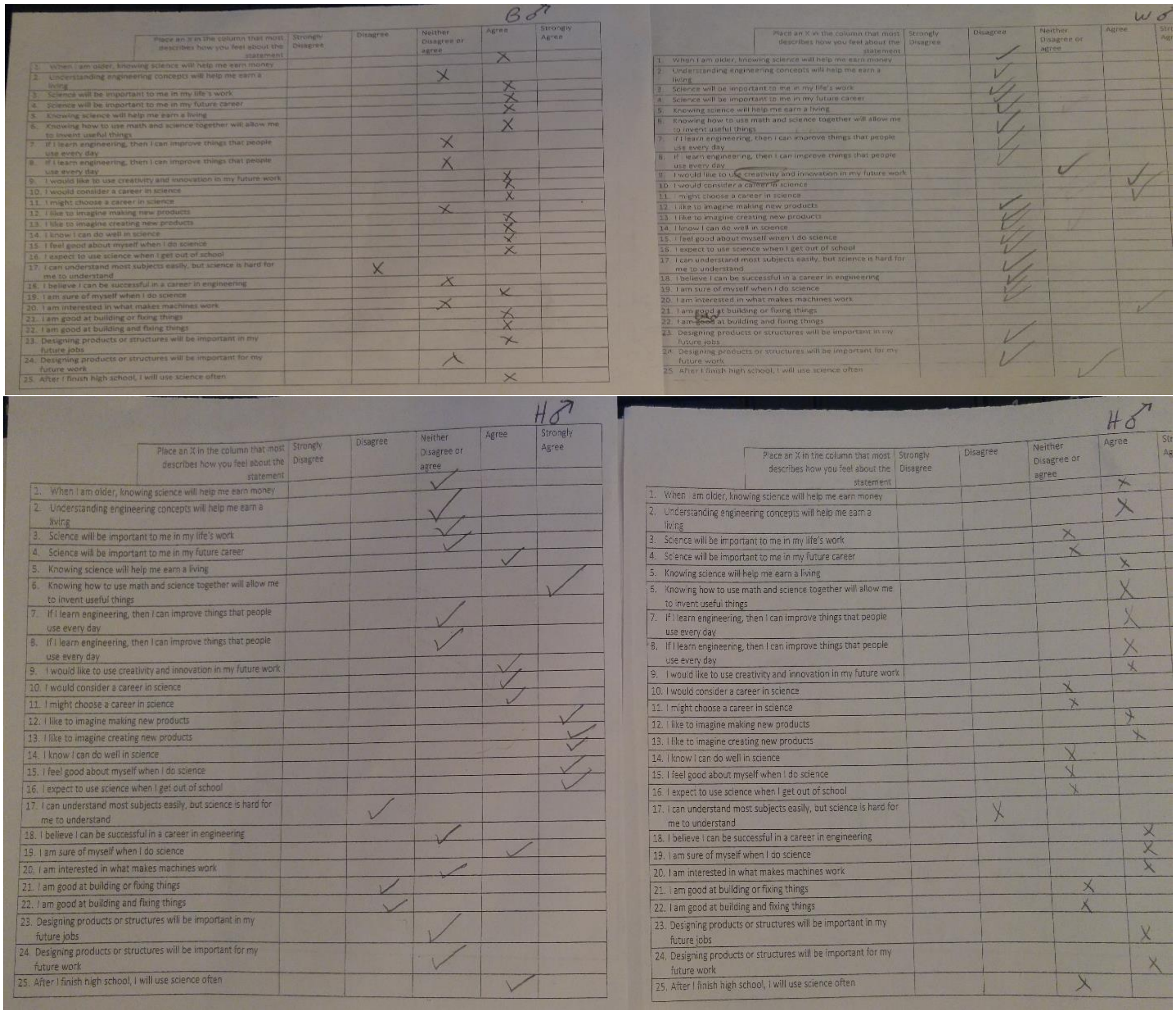
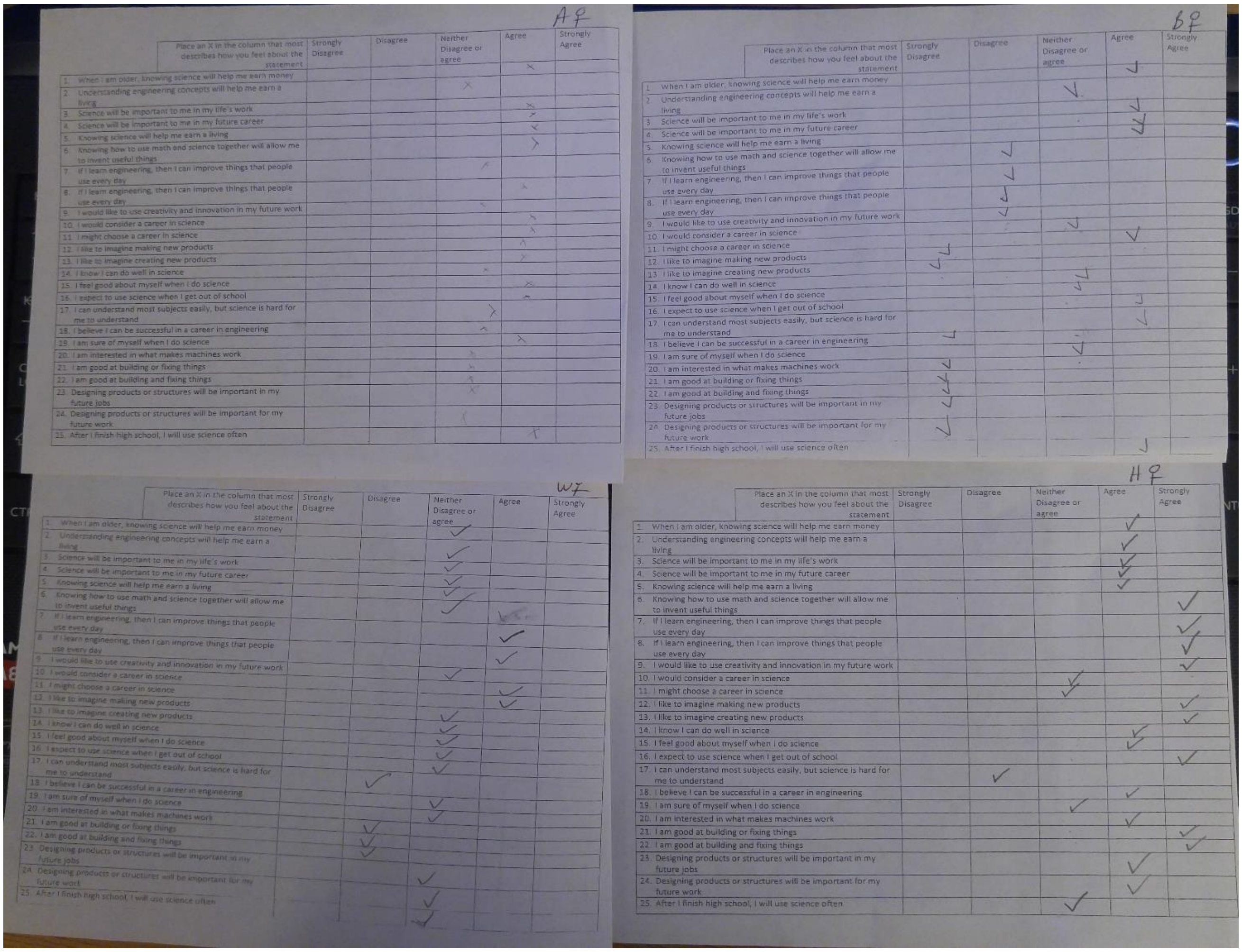


Figure 5: Examples of Post-Attitude Survey taken by a sample of demographics of students

Figure 5 (con't): Examples of Post-Attitude Survey



Conclusion:

In comparing the students' attitude towards science both via the Attitude Survey and formative assessment, I found that before the intervention most students did not see science as a choice of career unless they were already thinking along those lines. Most students confided in me that science was just a course they had to take and that they saw no use or correlation to future employment if they were not planning on becoming doctors or science teachers. Some students maintained a favorable outlook towards science because they felt the subject was fun and interactive. They could before the intervention see themselves working in a science related field.

The pre-survey drawing of an engineer at work revealed most students saw engineers as mechanics or someone who designed cars or repaired them. There were very few drawing depicting engineers as workers in the field of science or medicine. Those that said they knew of an engineer were referring to a parent or grandparent working as a mechanic.

The post attitude surveys showed a greater number of students either choosing science as possible career or agreeing that understanding science would improve their jobs. Most students were accepting of the fact that many aspects of their careers and adult life would involve some component of science and/or engineering. These same students showed having a better development of what an engineer does after the intervention. After the intervention, student became to see themselves as an engineer and not just the mechanic down the street. They showed to have an enlarged compass of the many jobs an engineer can and is involved in doing. This was evident by their drawings and discussions of how engineers have improved the lives of many through innovations in science, medicine, and technology.

In hindsight, I would dedicate more time to developing each intervention by following each session up with a lengthy discussion and using outside resources to pull real-world experiences in the form of relatable jobs and careers~~.~~

Literature cited:

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Permissions:

There is no permission needed to implement this Action Research Plan. All equipment and solutions are provided and approved to be used by UF Bench to Bedside CPET program and/or Palm Beach School District. I will share this Action Research Proposal with my Palm Springs Community Middle School Administration to solicit their support.

Appendix 1

Lesson Plan: The Pompe Predicament- Lesson 1 Looking Through a Father's Eyes

LESSON PLAN

TITLE: Daddy Help!

KEY QUESTION(S): What is Pompe Disease?

SCIENCE SUBJECT: Science

GRADE AND ABILITY LEVEL: 7^{th} Grade

SCIENCE CONCEPTS: protein synthesis and what constitutes a defective protein

OVERALL TIME ESTIMATE: 50 minutes

LEARNING STYLES: Visual, auditory, and or kinesthetic

VOCABULARY: lysosome, enzyme, DNA, protein

LESSON SUMMARY: This introductory lesson will cover a real-world story of a child with Pompe disease named Calum. The lecture and discussion will unveil necessary actions to develop diagnosis and cures for genetic disease.

STUDENT LEARNING OBJECTIVES WITH STANDARDS:

The student will be able to...

1. Describe an enzyme
2. Explain the role of an enzyme in the human body
3. Define gene and understand how a gene relates to a protein
4. Explain where a lysosome is located and its role in the function of a cell
5. Explain the genetics of Pompe disease

MATERIALS:

ESSENTIAL: Pompe Predicament Student Handouts per student
Pens or pencils per student

SUPPLEMENTAL: Overhead projector, internet, whiteboard, Teacher Manuel

BACKGROUND INFORMATION: See Pompe Predicament Manuel for background information.

ADVANCE PREPARATION: See Pompe Predicament Manuel for preparation information.

PROCEDURE AND DISCUSSION QUESTIONS WITH TIME ESTIMATES:

30 min: Divide class into groups and use Khoot to respond to questions as listed below.

ASSESSMENT SUGGESTIONS: Describe specific assessments for EACH objective:
For objective 1…What is an enzyme? What does it do in the body? Where is it formed?
For objective 2… Describe the role of an enzyme in the human body.
For objective 3… What is a gene? Where do the instructions for a gene generate in the body?
For objective 4… Explain the function of a lysosome and its location in the cell.

EXTENSIONS:

ACTIVITIES: Lesson 2 of Pompe Predicament
LITERATURE: Web quest of case studies involving Pompe Disease

RESOURCES/REFERENCES: Pompe Predicament