ELEMENTARY SCHOOL STEM EDUCATION

Interactive Qualifying Project Report

Submitted in partial fulfillment of undergraduate degree requirement

By

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Submitted to

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Abstract

Educating young students in the engineering field helps to increase their ability to analyze problems and develop critical skills early in life. The goal of this project is to utilize Tufts University's Novel Engineering Program in the first grade classrooms at John F. Kennedy Elementary School in Jamaica Plain in order to engage students in STEM programs at an early age. We will aim to break down barriers within the classroom and have useful tools that the teachers can use in the future for the students.

Acknowledgements

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Introduction

In recent years, science, technology, engineering, and mathematics, better known as STEM, have become essential in innovating and advancing education (Tippet, 2017). The focus of STEM education is on these 4 subject areas of study; however, these projects also cultivate skills such as: communication and cooperation, critical abilities, leadership skills, and organizational skills (Minnesota State, 2017). The tools from a STEM curriculum can be used for the purpose of the interdisciplinary application to real life problems. By learning the engineering design process early on, students will naturally use that process when solving everyday problems. While participating in STEM initiatives, students gain a rough understanding of the Engineering design process, which provides a guideline for how to approach a problem. As a result, the educational focus on STEM subjects at a young age has become a more important aspect of primary and secondary school curricula (Yoon, 2014). Still, there exists a large number of barriers that inhibit teacher's ability to successfully gain interest and invoke understanding about STEM concepts in students at the elementary level. For example, it is difficult to teach critical thinking and problem solving skills while applying STEM concepts because elementary students are in vastly different levels educationally. In order to apply STEM concepts, students need to first have a solid understanding of the basics in math and science. Thus, it is difficult for students to be able to understand the application of STEM if they still do not have a solid foundation of these skills (Difficulties With Mathematics, 2002). We are looking to adapt the concepts of STEM education to a first grade learning level in a fun and creative way. In doing so, our goal is to instill an early understanding and appreciation of interdisciplinary education while promoting an interest in STEM topics that will lay the foundation for a successful future in the field.

The specific elementary school classrooms we are working with have students that speak English at varying levels of proficiency; therefore we need to investigate different ways to teach across language barriers. This becomes a multifaceted problem when we not only have the language barrier to work around, but also have to take into consideration the students young age and the availability of teaching resources (Alberta Education, 2007). Resources such as picture books are commonly used for students to learn the language and also having extra teachers assistants to take the time needed for these students to catch up on the english language. Low reading level novels containing pictures are chosen for students new to the language for word association. The use of illustrations allows teachers to appeal to all students through visual and practical learning. The last issue is that the teachers do not have a good way to chart students progress at this age. The classroom studied for this project has a need for an assessment tool geared towards the young students without being too rigorous for first grade ESL students (Martha Jones, personal communication, September 14, 2017).

STEM education at the high school and collegiate level is typically contingent on understanding advanced concepts in fields of study such as calculus, physics, coding, and biology, to name a few. It is important to note that it is not feasible to expect elementary students to be able to grasp such advanced curriculum. Instead, we should be looking for creative and enticing ways to conceptually introduce this subject matter with the expectation that it will induce a future passion in the field of STEM. One of the most outstanding teaching resources for students of this age is picture books. In our project we will be looking to identify simple issues in picture books that can be addressed in a creative and enjoyable manner while introducing a comprehensible engineering design process. In doing so, the students will be introduced to basic STEM concepts that will lay the foundation to be more successful in later endeavors to learn the aforementioned advanced concepts. By using simple projects students who are on different learning levels can cooperate with one another and have the opportunity to think differently. Creating an atmosphere where students will enjoy learning and eventually will see how the engineering design process can be applied to other subject areas and aspects of life.

We will be developing a way for first grade teachers to effectively introduce the concepts of STEM. In order to accomplish this, it is important to develop a quantitative system that allows the teachers to gauge the effectiveness of their curriculum. We will be developing a system of assessment that is user friendly to not only the teachers, but the students as well. As a result, the system will give the students incentive to improve and will give the teachers the necessary data to refine their curriculum.

The importance of STEM education extends far beyond just an elementary school classroom. Giving children a solid foundation in STEM education sets them up for future success because they will be afforded with the necessary critical thinking skills to approach any sort of problem in a logical and thought out way. Scientific advancement has been and will continue to be the driving force behind societal development; and the sooner we can get the next generation of scientists, engineers, or mathematicians to be exposed to science, technology, engineering, and math the better off they and the world will be.

Background

Classrooms at the John F. Kennedy (JFK) Elementary School in Jamaica Plain have a wide array of demographics which create a unique learning environment for both the students and teachers. (Mass DOE, 2016). The varying demographic is the cause of several educational delays. The Performance Data Overview collected by race indicates that during the last academic year 40.2% of the students enrolled at the JFK Elementary school received the designation of ELL or English Language Learner (RACE, 2016); meaning that English is not their primary language. Issues with language barriers are significant challenges that the teachers and students at the JFK Elementary School face on a daily basis.

Such obstacles include: a number of different languages from varying countries such as Haiti (10.2%), China (8.9%) and Dominican Republic (8.3%) (American Community Survey, 2010). This is caused by a large population of immigrants from these backgrounds settling in Jamaica Plain, where 23.2% of the residents were born outside of the country.

Many students that attend JFK elementary come from low income backgrounds. Jamaica Plain has low socioeconomic status, which correlates to less funding in schools and less resources (APAA, "Education and socioeconomic status"). The students require more attention in order to learn the new language and the first grade curriculum, so greater resources are needed to help overcome the language barrier. These resources can be teachers who speak the language, specific classes, and exercises that help teach the english language to a student, but they are more than a classroom of english first language students require so more funding is often needed. Due to the lower economic state of Jamaica Plain, JFK Elementary School receives less funding from the state and is a contributing factor to the educational problems that plague the classrooms. On average the 120+ schools of the Boston Public School System received $4,077,741 in funds to operate for fiscal year 2017, and JFK only received $2,996,790 for fiscal year 2017 (Boston Public Schools 2017). This nearly $1,000,000 difference puts the school at a disadvantage, because with additional funds the school would better be able to combat the language barriers present in every classroom. Educational resources being prevalent has been found to often tie into the higher commitment to learning in the students and a higher commitment to education by the teachers (Hofmann-von-Baltenau, 2016).

The varying ethnic backgrounds and the language barriers that come with them makes the arduous task of educating the first grade students on the areas of Science Technology Engineering and Math (STEM) more difficult than the average US classroom and requires greater effort. Keeping the attention of a first grader for an extended period time is hard when they do understand what an instructor is saying. When a student comes to the school and doesn't speak English it can be very difficult to teach them and break through that communication barrier (Hofmann-von-Baltenau, 2016). However, there are some benefits to having a diverse classroom; "sometimes the results are positive and students get to know each other, come to appreciate and value the vitality of diversity, learn how to use diversity for creative problem solving and enhanced productivity" (Johnson and Johnson, 1994, p. 58).

STEM education is typically geared towards older, more advanced learners because it is difficult to breakdown into concepts that are easy to grasp for elementary students. STEM education is a relatively new concept even though innovation in fields of science and engineering create jobs for the majority of the workforce (Successful K-12 STEM education, National

Academies Press, 2011). For that reason, the United States is trying to push it to the forefront of academic curriculum (U.S. Department of Education, 2015). A study done by the Committee for Economic Development found that 38% of college students that initially intend to get an undergraduate degree in STEM do not actually graduate with one. This information is further supported by data from the National Math and Science Initiative which states that 69% of high school graduates are not prepared for the STEM curriculum presented in college (Oberoi, 2016). These numbers are alarming, but it is crucial to understand that it is not simply a lack of preparation at the highschool level that causes the discord.

One of the most significant factors that limits students seeking to excel in STEM in the United States is the lack of curriculum for students at an elementary level. A study done by Teach for America found that “just 1 in 4 fourth graders from low-income backgrounds are proficient in math, and just 1 in 6 are proficient in science” (Teach for America, 2017). This data has a direct correlation to the small presence of STEM education in elementary schools nationwide. By contrast, it has been proven that introducing STEM to students at an early age helps to develop important critical thinking and problem solving skills (Kroeger, 2016).

Second, the fundamental problem with STEM education in the United States is the inability to adequately prepare teachers to present the curriculum to students at a young age. Boston Public Schools requires teachers have a valid teaching license for Massachusetts by passing the MTEL (Massachusetts Tests for Educator Licensure) for the subjects and grade level they wish to teach (Boston Public Schools, 2017). The MTEL elementary school test consists of a general curriculum (multi subject + math subtest) and a foundations of reading test (Department of Education, 2015). The problem with the basic skills test is that most applicants can pass by achieving just a 40% and the concepts typically only cover 6th and 7th grade curriculum (National Council on Teacher Quality). Overall, the United States is not as strong as it could be in the global economy due to poor scores in science and technology (Oberoi, 2016). This is largely due to the fact that in the past little attention was concentrated toward STEM and now the public education curriculum is changing and pushing more towards a STEM plan. For this reason, there are multiple government initiatives with monetary incentives for nonprofit organizations and public/educational agencies. In 2015 the United States government invested $110 million toward the STEM Innovation Network program which focuses on assisting schools in developing their STEM program through training teachers (U.S. Department of Education, 2015). At this point in time, the government is working towards creating more jobs in the industry and pushing STEM education, but the struggle is properly dispersing resources and determining the most effective way to train teachers and present the new curriculum.

The benefits of a STEM education, even at the elementary level, serve as both a mental and financial advantage for students. More lucrative job opportunities as well as a more advantageous skill set are the byproduct of undergoing a STEM focused education. Persons entering the workforce with a STEM background are significantly more economically comfortable when compared to their non-STEM educated counterparts. "Documentation of such an outcome was evidenced in the most recent economic downturn when the mean salary of persons with STEM skills was $84,400 relative to $45,400 for other workers" (Burston, Collier, Rhodes, 2016). Another aspect that having a STEM background assists is job security; "workers in general were experiencing 9.4% unemployment, STEM workers had an average unemployment rate of less than 5%" (Burston, Collier, Rhodes 2016). Educating elementary school students at JFK with a very basic level of STEM education, could spark an interest in the field which would have significant financial ramifications. STEM education is important both for the personal gain it can offer an individual as well as the economic impact it can have on the United States. In recent years, STEM jobs have shown two times the yearly growth of non-STEM jobs and allowed the average worker to earn 26% more than people in a non-STEM profession (Kroeger, 2016). This data suggests that employers are willing to pay more for innovative and well skilled workers. Gaining expertise in a STEM profession rewards people that are willing to receive extensive training and perfect skills pertaining to critical thinking and problem solving. This claim is backed up by a study done by the U.S. Congress Joint Economic Committee which determined that there is a strong demand for STEM workers due to a decrease in unemployment rate and wage increase in the field (Casey, 2012). The economic benefits of innovation and employment are clearly on display in metropolitan economies that are STEM-oriented (Rothwell, 2013). Still, while the demand for STEM workers increase in the United States and our education system aims to put more emphasis on receiving a STEM degree, we are not performing nearly as well as we can.

The Novel Engineering program that the STEM curriculum at JFK is based on aims to develop key skills that will make them successful in their academic endeavors and beyond. One benefit of Novel Engineering is allowing “students to practice important 21st century skills such as teamwork and communication”(Novel Engineering, 2017). Additionally, STEM education programs, such as the one established at JFK, aim to teach students critical thinking skills. A generic list of objectives for a STEM curriculum following the Next Generation Science Standards may appear as follows:

3-LS2-1 : Construct an argument that some animals form groups that help members survive.

3-LS4-1 : Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago.

3-LS4-3 : Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well and some cannot survive at all.

3-LS4-4 : Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

(Burston, Collier, Rhodes 2016)

The John F. Kennedy Elementary School has identified STEM as being an important area of study for its students. This is evident by the application the school submitted in 2013 to receive the designation of being an Innovation School. The basis for the proposal was the "integration of Science, Technology, Engineering, and Math (STEM) into the curriculum" (A Continuing Journal Innovation School Proposal, 2013). The staff at JFK made the argument that their use of the Engineering Design Process and the application of STEM to their curriculum will allow students to expand their thinking as well as allow the students to "become more flexible thinkers, creative problem solvers, and have a greater stamina for mental tasks" (A Continuing Journal Innovation School Proposal, 2013). Providing the elementary school students at JFK with an introduction to the STEM field will help them to be far better off in terms of their future during schooling as well as in their professional future. Through this Interactive Qualifying Project we will facilitate the JFK staff with their implementation of a STEM based curriculum by providing feedback in the form of additions and possible improvements to their existing STEM education structure.

Literature Review

ESL

Students with English as a second language often have a harder time learning in a classroom environment due to lack of understanding english at the classroom pace. But in order to create the “best and brightest” students for the future, STEM education is specifically important to ESL students (Journal for Multicultural Education, 2016). They can apply the English that they have learned, into other subject areas in order to see the application of certain words, thus broadening their vocabulary and English speaking and writing skills. When these students and their classmates who have English as their first language are integrated, students are able to develop their English language abilities in all subject areas (Alberta, 2007). Students who fall into this category of English second language (ESL) oftentimes learn better when working with other students of varying levels of English. Usually, their peers know how to work and explain some of the educational material better to these students than a teacher would (Alberta, 2007).

Next Generation Science Standards for third grade students compared to the Common Core are very similar yet they assume students will have certain skills within a certain subject, such as being able to infer things in science, or being able to ask and answer questions in reading and writing (Journal for Multicultural Education, 2016). Yet, many of these skills may not be present within an ESL student because they are still developing those necessary language skills to meet those standards in order to analyze things or make assumptions. Some of the keys of math, such as restating questions into answers, asking questions, and paraphrasing, are keys within the English language. Science also carries a lot of these same concepts.

Another key task teachers must keep in mind when working with ESL students is in making teams within the classroom are ensuring each group has a good mix of ESL students and strong English speaking students to support those ESL students. Making these groups have specific tasks and roles is another key to making these groups successful in the classroom. If these things are not kept in mind, it can create an imbalance within the classroom and within each group. This would cause students to feel unincluded in learning.

Ensuring students can feel comfortable in working with a group of students and integrating English learning concepts will be key when we move into the classroom and begin creating and completing the engineering experiments with the first grade students. For our project, teaching STEM to students is also key to aiding their English learning. With the high percent of ESL students in the classrooms we will be working with, these are all very important factors to take into consideration as we move forward with this project.

Early STEM Education

As stated in the intro, STEM curriculum enhances many aspects of learning in other subject areas and everyday problem solving. Due to the benefits of the learning style, STEM education has been getting implemented in classrooms starting at a young age. One study showed the effects of a student who focused on the students increase in engineering identity (Yoon, 2014). Engineering identity is a combination of a student's availability of Science Technology and Engineering (STE) education, their own belief in their academic abilities, their gender identity, and student's role models. In the past, STE was strongly defined by men. As of 2009, men were 51% of the work force (people over the age of 16 with a job), yet men have 76% of STEM jobs (U.S. Department of Commerce, 2011). This study focused on using STE education with a heavy focus on engineering to show that a student's engineering identity is not static. The study showed the engineering identity, which is similar to student's perception of their capacity to learn, can be increased in the proper learning environment.

The study followed 891 2nd, 3rd and 4th grader students in 59 classrooms and the teachers taught modules as directed. Growth was measured in four branches of knowledge, science, work of engineers, engineering design process, and technology related to procedure. The findings show positive increases in the learning ability, however the improvements in engineering ability made in grades 2 and 3 were less as compared to the 4th grade students. This is expected to be due to certain modules being above the student's current ability level. This study provides evidence of STEM education increasing knowledge in specific academic areas as well as creating a more stable identity as an engineer for the elementary school students. Also is important is their outlined process of charting young students improvements which is applicable to our project. The data collected was difficult to analyze because the increases in knowledge are difficult to determine the cause. However, their procedure shows a possible method for the students at JFK Elementary by outlining the areas to measure to chart growth of the student's engineering identity, such as pre and post tests and Student Knowledge Tests. (Yoon, 2014).

A different STEM education study researched at the pre-kindergarten level. This study could be a great building block for how the project at JFK elementary. Due to the demographic, many of the students are coming into the classroom without a strong reading level or STEM background (Martha Jones, personal communication, September 14, 2017). This study on pre-kindergarten students analyzed five categories: classroom observations, early childhood educator interviews, student work samples, student focus groups, and parent questionnaires. The results from these five data sets revealed the value of starting engineering at a young age aided in fostering curiosity and interest in learning, by using captivating activities based on asking questions and design. The downfall of this study is that it was conducted on a single classroom, most of the data was generated from interviews and there is not much quantitative data generation, the only quantitative data was from the parental questionnaire. This study has great examples of STEM modules and how we can build off of their assessment techniques (Tippett, 2017).

A 2014 study noted how many downfalls of early STEM education resulted from the lack of teacher preparation. This study aimed to research effects of a well developed STEM-preparation module for teachers. The researchers hypothesized if there is a well designed preparation module the students STEM knowledge will have a greater increase in teaching efficacy, pedagogical practices, and STEM literacy (Rinke, 2016).

Novel Engineering

There are many different ways to teach STEM initiatives. The JFK elementary school uses the platform of Novel Engineering designed by Tufts University which are projects based on the literature students read in their Language Arts class (Novel Engineering). Through the projects, the students will refine skills such as critical thinking, problem solving, and group cooperation as they work to creatively address problems presented in the books. The projects the students at the JFK elementary school engage in teaching these skills, in addition to the engineering design process. Martha Jones and her team have created a design process which they believe is understandable to their students. The process is as follows: ask, imagine, plan, create and execute, and revise.

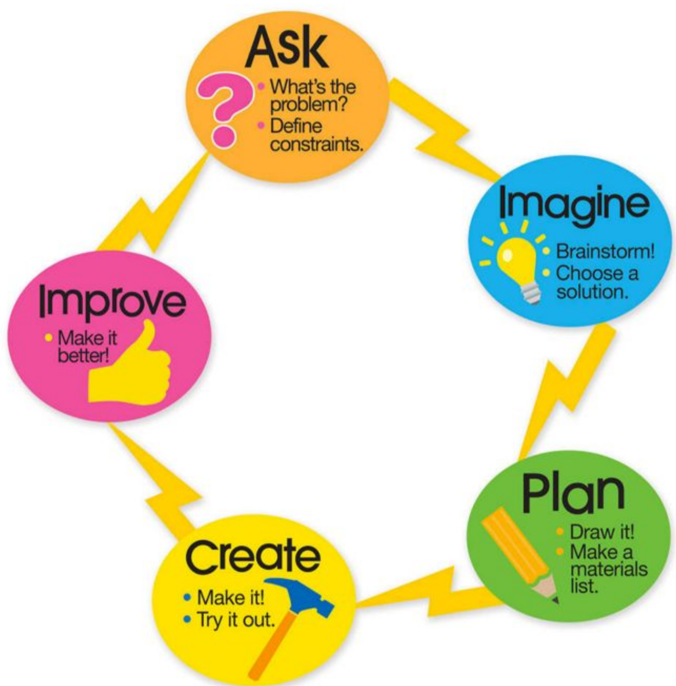


Figure 1: Visual representation of the engineering design process

This interpretation of the design process is a simplified version of the design processes people in higher education or the work force use, which helps the elementary students to form a general understanding of engineering while giving the students the knowledge of general problem solving, due to the versatility of the engineering design process' application.

The projects the teachers give the students are usually more broad and do not have many constraints (Martha Jones, personal communication, September 14, 2017).

The learning skills the Novel Engineering projects teach do not just challenge the students. The teachers are faced with challenges of staying in their budget, student variation of learning levels, and engaging the students. When a new project is started it is imperative to create and find ways to engage the students in the project. One way Novel Engineering suggests to keep the students as active learners is to have the students work on identifying the problem together while they're reading through the book. Through these group discussions students can learn to identify and understand the need of the characters/clients in addition to the problems present in the book (Novel Engineering, p. 5). These discussions help the students to participate and also are key in teaching the students lessons of teamwork, problem solving etc.

Methodology

As we move forward into the implementation part of our project, we decided to break it into four stages: the introduction presentation where we will introduce engineering to the students, an observational day where we can observe the classrooms and see the dynamic of each of them, a Moon Bear unit which we will be constructing projects for the books read in class, and the rubric which teachers can use for all future engineering projects. Each of these parts of the project play a critical role in finishing out the project and ensuring the teachers will be able to build on it in the future. In each stage we have identified steps and tasks we need to accomplish before and during each stage. In addition to these steps we plan to implement a Scaffolding teaching strategy throughout our project which will aid in the learning process for the students.

Introduction Presentation

In the preliminary stages of the STEM initiative the teachers believed it would benefit us and the students to have the project team come into the class and deliver a presentation. The presentation started by each of us introducing ourselves and a simple brief description of our majors. Since a goal of ours was to make the activity engaging for the students we decided to make our presentation short, five minutes, making sure there were many relevant pictures attached to each slide to be used for explanations. The goal of the presentation was to outline what an engineer is and introduce ourselves. At the conclusion of the presentation the we lead a quick 20-25 minute activity. The activity started with the teachers pairing the students into groups of 2 based on their knowledge of what students performed well together. After the groups were set off to identify the problem, build a tower with marshmallows and toothpicks as high as possible. Once the students were given the problem they progressed through the engineering design process step by step to solve it. The engineering design process the students adhere to is as follows: ask, imagine, plan, create & execute and revise. In the ask stage, students identified the problem verbally. In the imagine stage, the students created drawings on how they want to build their tower. In the plan stage, the students coordinated themselves to prepare designs for the next stage of building. The create and execute phase of the process began when the students built their tower. After all the towers were completed, the students looked at the other groups' towers and see what worked well and what did not. Then the groups reassembled for the final stage of the process, revise. The students discussed where they think their project performed well, where it performed poorly and how it can be improved. The goal of the activity was to get the students excited, moving and engaged while exposing them to the basic engineering concepts they are starting to become familiar with during the novel reading projects.

Observations

Phase two of our project at JFK Elementary we observed the teachers deploying the *Strega Nona* module. This portion is hands off and we observed the classroom dynamic in the individual classrooms for Ms. Jones, Mr. Nunez, and Ms. Coughlin's classrooms to gage where the students are at and get a baseline for when the *Moon Bear* unit is taught. This observational day will serve as the starting point to chart the student's progress in the areas the rubric created. The rubric focuses heavily on the engineering design process that was discussed in the Tufts Novel Engineering manual (Novel Engineering, 2017). The rubric will associate tangible traits in students that an observer would use to measure strength or weakness in the areas of the engineering design process and associate certain behaviors with a level of mastery in the engineering design process: ask, imagine, plan, create & execute and revise.

Strega Nona is a children's novel, centering around Strega Nona, a witch doctor that aids the town in its various problems. Strega Nona assists the character Big Anthony to help with her magic pasta that feeds the town. Big Anthony pays attention to how the magic pasta pot turns on, but does not realize how to turn the pot off by kissing the pot three times. In this story, Big Anthony was then in charge of the magic spaghetti pot and does not turn it off. This results in the town being over ran with spaghetti. In the story, Strega Nona turns the pot off with three kisses. The solution for the excess of pasta in the novel is that Big Anthony is punished for his lack of attention and his punishment is that he has to eat all of the pasta and then he is full when he eats all of the pasta. (*Strega Nona*)

The students first broke up into groups, by the classroom's respective teacher in the same manor as phase one, with groups being composed of students with different strengths to enable a strong team dynamic to enhance the student's interaction during the project.

In this unit, the children used the engineering design process to identify the problem in the book *Strega Nona*. That problem is fairly straightforward to identify; how should Big Anthony remove the large amount of spaghetti covering the town? This covers the first portion of the design process in the unit which is "ASK?". The project then involved building a model that could remove fake pasta in their own creative way.

Then in these groups, the next step is "IMAGINE". This stage had each group brainstorm a number of possible solutions and is intended to be open ended to foster creativity in the young students for how to get rid of the excess pasta.

The "PLAN" phase involved designing the intended plan. They sketched their plans for how to solve the problem and helped the students have a framework for what they built to combat the pasta.

“CREATE & EXECUTE” implemented and tested the plan that the students designed by utilizing recycled materials and building the model that will remove the pasta in the scenario. They tested this model with the fake pasta that was set up and saw how their plan works.

Lastly, “REVISE” was when the students gathered together and assessed the success and downfalls of their process. This involved critical thinking and is an important aspect of these projects.

While observing, we looked for student engagement in particular and how the students provided their thoughts to the group. Student engagement was tracked to see which areas the child excels in and pay close attention to where student's strengths in different school subjects carry over to a group dynamic. Additionally, we looked to identify how interactions between students and teachers differ from students and peers in order to gauge how comfortable they are in sharing and taking ownership of ideas (Booren, L. M., Downer, J. T., & Vitiello, V. E., 2012). A student being more extroverted or introverted also affected how the ideas can flow through a small group. ESL student participation is also a point of interest to see how the language barrier affects class group work. Depending on the behaviors seen in the three classrooms we are planning to develop a specific incentive program to increase engagement. We also plan to make the incentives not purely for participation so a more introverted student will still receive a reward for productive thoughts in a group.

As we observed during the “Three Little Pigs” unit. Many of the students were quick to ask for help and supervision however some did demonstrate more introverted tendencies. To address the introvert population we would go up to them and ask if they need our help, and although shy, the students did accept our assistance. We did take note that during the group discussions at the end where students were asked to share ideas it was the same group of students speaking aloud and sharing their ideas. Here would be a opportune time to utilize some sort of incentive to get all students to participate. Doing this in the future will hopefully allow the introverts in the class to participate more in group discussions and come out of their shells.

Moon Bear Unit

The teachers at the JFK elementary school requested that we put together our own unit based upon the *Moon Bear* series, written by Frank Asch. *Moon Bear* is a children's story book series in which the main character, Bear, faces different challenges; which are often the result of Bear taking something too literally or misunderstanding a situation. The focus for this task will be to create a unit, structured similarly to previous units, which was taught in February or March on several of the *Moon Bear* short stories.

We synced our project design to the engineering design process that the school currently uses during STEM projects. The phases of the process are: ask, imagine,plan, create and execute, and revise. The intent for the inclusion of this engineering design process was to encourage the students to think creatively and critically while working together as a team.

Our *Moon Bear* unit looked like the following. After dividing the classes into groups and giving them a *Moon Bear* book to read, students conducted a character study where they looked at *Moon Bear* and the problems he faces in the story; this aligns with the ask phase of the engineering design process. The students were then given a list of constraints to limit the solutions that they come up. We then facilitated a brainstorm session as part of the imagine phase where kids created a list of possible solutions. After the brainstorming session the students were instructed to select a single solution and enter into the plan stage where they used the "Think! Sketch! Label!" idea (pictured on their engineering design process poster in the classroom) on their idea they came up with in the brainstorming session prior to implementation. The implementation phase is known as the create and execute portion of the engineering design process; here the students made a prototype of their solution and tested it to see how it works.

Finally, during the revise phase, the students self assessed their own performance and reflected upon how they could possibly alter their design to make it better. This is a critical portion of the lesson because it allowed students to share their own ideas and assist others in making connections.

Rubric

When creating the rubric, we interviewed the three teachers at the JFK Elementary School. In discussing with the STEM Education Center at WPI, we found that in order to create the rubric, we must discuss with the teachers to establish the overall objectives they have for the engineering problems the students will do in class. The rubric is dependant on if they wish to focus more on outcome of the projects, the engineering design process, etc. The teachers' main goal was to focus on the student going through each step of the Engineering Design Process. After this, we compared this to the Common Core criteria as well as the Next Generation Science Standards that are in place in Massachusetts. Observation in class will also be key to creating a rubric teachers can use to grade students. Some of the things we will want to look for in the observation day are how students interact with each other, how they look at problems and what the different academic levels are within each classroom. Now that we have the baseline of what we are grading students on and what the standards they need to meet by the end of first grade, we can created a rubric that can be used for the entire engineering curriculum in the first grade at JFK Elementary school. We created a scale of how the students are graded and a description within each category to explain to the teachers and to the students, what exactly they are being graded on. We kept the descriptions short but descriptive enough that should other teachers receive this rubric, they will be able to grade students according to the same standards. See Appendix A for the rubric.

With this, it is important we know how students feel about their own skills and ideas. We also created a self-assessment that is very basic and any students depending on their academic level, will be able to use and assess their skills in a basic three smiley-face tool. It is divided into the five steps on the Engineering Design Process, with a smiley face, medium face and sad face that students can color in to tell themselves and the teachers how they feel about each topic. Each teacher can decide if they want students to use this tool as a before and after grading sheet for themselves or if they just want to use it as a self assessment tool for the students. See Appendix B for the student self-assessment tool.

After discussing this draft of the grading rubric with the teachers at the JFK Elementary, we were able to take the points they mentioned and implement them into a new draft. The edits we made can be seen in Appendix F. We needed to clarify the different boxes. 4/4 is the goal by the end of the year, having students able to do all part of the Engineering Design Process by themselves, with little to no help from the teachers. This updated rubric will be able to track the progress of each student needing help during each stage, since we saw many students needing help continuously. From project to project, we should be able to better track the progress of each student with the updated rubric.

Scaffolding

Scaffolding in our project allows us to assess the different types of learners in our class and cater to their individual needs. Some commonly used scaffolding techniques include show and tell, reversion to previous lessons or skills, peer to peer learning, visual aids, and debriefing as a means to tie down lessons (Alber, 2014).

The show and tell technique has two different aspects. This is a tool that can effectively be used by both the students and teachers. As a teacher, it is often beneficial to provide students with a model prior to their students engaging in the project. Showing and presenting the model to students also allows the teacher to effectively lay out project expectations while providing a visual aid that gives students a final product to shoot for. Furthermore, enabling the students to present their work to the class gives them a sense of ownership in what they create (Alber, 2014)

Additionally, it is important when teaching to map out your lesson plans to ensure they connect and build on one another. In doing so, this allows teachers to revert back to prior experience and have students build on prior knowledge. For example, if the first grade students are working on addition in everyday math class, it would be helpful to tie addition into our STEM education project. This would allow the students to tie down their addition skills while incorporating something they are familiar and comfortable doing to a project that may seem intimidating or difficult (Alber, 2014).

Peer to peer learning is a really powerful tool to engage students and allow them to work together. It is easy for teachers that have complete mastery of material to misidentify potential roadblocks students may face as they try to understand a lesson. Having a mutual perspective from another student often allows them to work through difficult concepts together. Additionally, by identifying the different types of learners in a classroom, a teacher can intentionally pair students together whose skill sets complement one another (Alber, 2014).

Visual aids, otherwise known as graphic organizers, are beneficial to the student learning process in two main ways. The first of which is that visual aids allow students to visually represent their ideas; which is a more effective for those students who are unable to grasp concepts quickly. Secondly, visual aids allow students to organize information and understand the sequencing and/or cause and effect relationship which may be present in the lesson. This scaffolding technique is comparable to the use of training wheels on a bike in the sense that visual aids are meant to guide and shape (Alber, 2014).

Debriefing or in simpler terms: pause, ask questions, pause, review is a scaffolding technique which ensures that students fully understand the problem or idea presented to them. Fundamentally the instructor introduces a new idea, pauses to allow the students to soak in the new information, poses an open ended question to the students to test if the knowledge was absorbed, pauses again to let the students think about their answer to the question, and then reviews the student responses to the question as well as the reviews the new concept as needed. The benefit to this scaffolding strategy is that it tests the students on their knowledge of a concept before moving on to new concepts (Alber, 2014).

Since there are many ESL students, we will seek to include more visual aids and hands on activities that still effectively drive home the Engineering Design Process. Further, since we are working with first graders, it is important that they take ownership in their projects and the work they do. For this reason, we will take a show and tell approach that allows students to put their work on display for the rest of the class and give an explanation about their thought process.

Observations

Introduction Presentation/ Activity

The first visit to JFK elementary school involved giving each first grade class a presentation on what STEM is and how the Engineering design process aids STEM activities. An introductory project that involved building towers made out of marshmallows and toothpicks was used to reinforce the topics of the engineering design process. In each classroom the students were split into groups of two after receiving the presentation that introduced STEM and the marshmallow tower project. The project was broken into the steps of the design process Ask, Imagine, Plan, Create and Execute to assist the students in following the process the classroom focuses on.

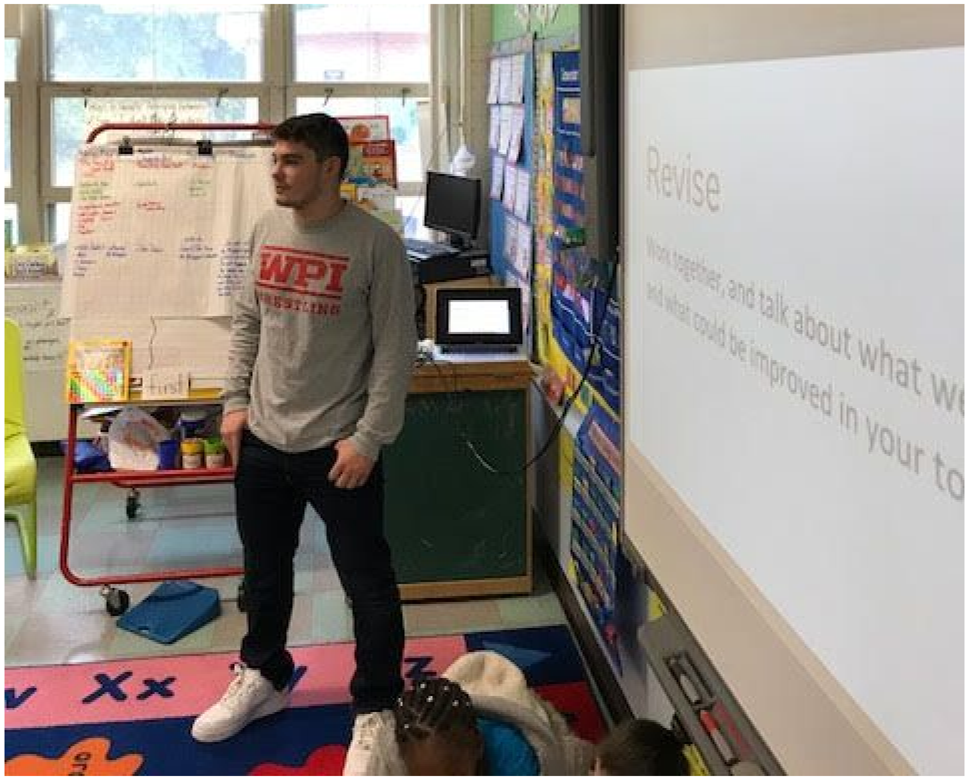


Figure 2: Andrew Ellis leading the "Revise" section of the presentation

Across the three classrooms, it was observed that each teacher had a different combination of students that behave differently and create three distinct classroom environments. Visiting helped identify challenges in each class. Martha's classroom had a larger population of ESL students than the other two, which needs to be taken into account for how to effectively teach this class. Certain students did not speak any english so communication was difficult. In addition there is a student teacher in Martha's classroom. Hannah's class has a few students that often misbehave or get distracted. Managing classroom behavior is an emphasis. Mr. Nunez's classroom was similar to Hannah's with behavioral issues being a challenge with teaching. Mr. Nunez' also has a teacher's aid in the classroom.

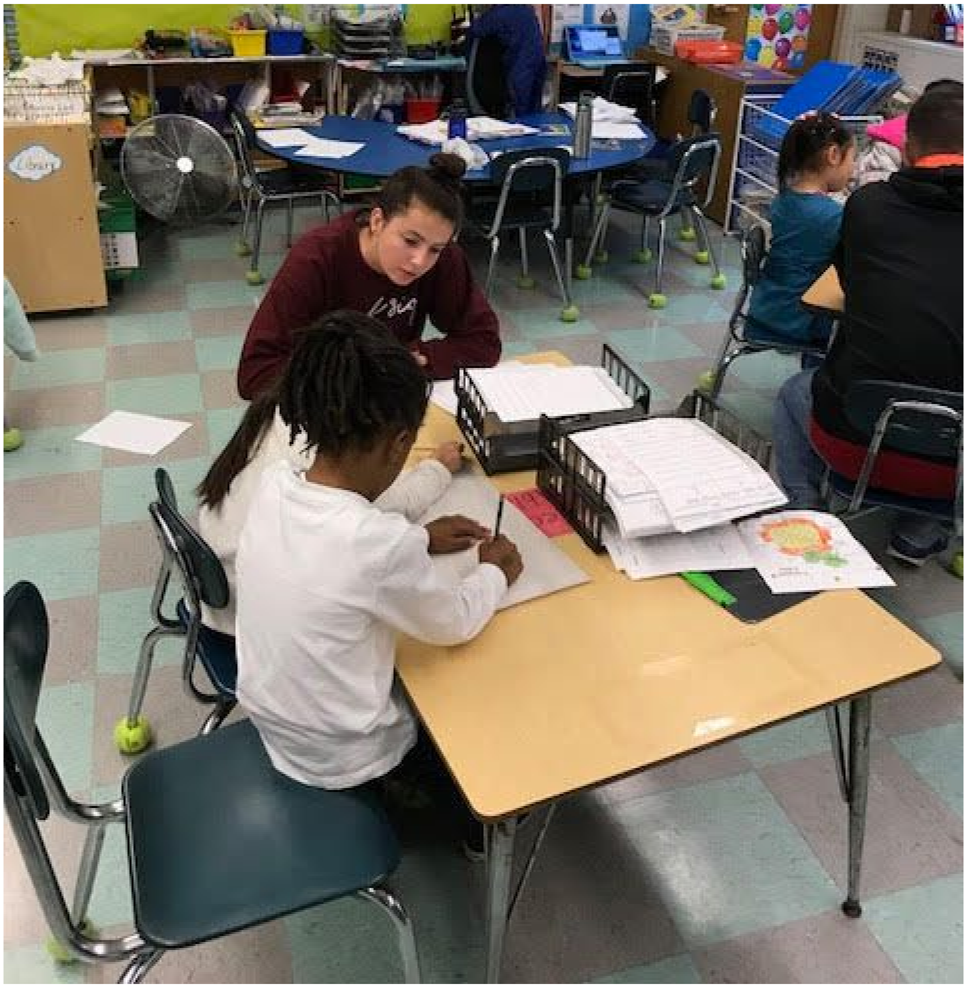


Figure 3: Rosie McCarthy assisting students in planning their marshmallow tower

The first grade student's of JFK were excited when our group presented to them and were eager to work with us. Each first grade student was well prepared for our visit because they discussed what engineering is beforehand and had many ideas of what engineers do. The groups did very well with the presentation and participated very often. A few students had to be ignored due to them participating too much and overshadowing the other students. Group work was another struggle because the students in each group of two would each have their own ideas and build two towers sometimes instead of one for the team. The students needed to be encouraged to work together multiple times during the activity due to this. Also the students struggled with turning their plans that were created on paper into a 3D model with toothpicks and marshmallows. Encouragement was required here to help the students realize that they are able to create the tower. One area the students were great at is creativity. One student thought wet marshmallows might stick better, students reinforced their structures with multiple toothpicks, and they built well off of each others ideas.

“Strega Nona” Unit

During the visit to the JFK elementary school two members of the group met with Martha Jones in her classroom for approximately 40 minutes. The members were then split up and sent to the other 2 classrooms individually to assist and observe the students. During this time period the group members walked through the classrooms taking note of things such as: communication between students, teaching method discrepancies between classrooms, and general student behaviors. Once the activities were over the group members met with the teachers and discussed what they had saw. To much surprise of the members it had almost seemed as though the teachers had just ran a test on their teaching methods. Each teacher discussed what they had done in their classroom and how it affected the students and their learning behavior.

In Martha Jones’ classroom we noticed that many of the students followed the same idea. There were not many constraints on the project in Martha’s room which brought up the idea that in the future more constraints should be placed on the projects in order to promote more critical thinking. Without constraints the students were able to choose any solution to the problem, most of which were impractical. Another topic of discussion that came up was group work. We discussed different aspects of each room and came to the conclusion that it can be very hard to get the students to work together, but were still undecided on what method of interaction is better for the students; Having the students work individually or together.

Figure 4: The materials the students used during the project

In Mr. Nunez' classroom the students had the choice to work in groups or individually. This proved to be interesting, many students chose to work individually which made monitoring all the different project a little more difficult; However, Mr.Nunez did have some constraints on the project one which helped guide the project. One constraint was to build the pasta remover on a plate. The plate was considered to be "the town" Strega Nona lived in, giving the students a visual of the area they could work with. Providing visual constraints for the students seemed to help guide them to developing practical solutions. Another example we saw of this was in Martha's classroom she brought in actual pasta and made sure the students recognized their project had to hold the pasta.

In Hannah's classroom the students were all working in pairs. While this allowed for some stronger students to help others, it had varied results. In some groups, the students worked very well on one cohesive project. On the contrary, some groups featured a pair of students that worked on their own separate projects while in a pair. Further, there was some turmoil in the selection of materials. Materials were brought in by the students and the teachers. However, students were not guaranteed the materials they brought in. This did not present a problem, but there were some issues when groups were selected at random and materials were chosen on a first come, first serve basis. After speaking to the teachers following the activity, it was decided that it would be beneficial in the future to place more restrictions on the materials for the project. In providing a set list of materials at the onset of the project, students would then design and draw their project using the given materials. This approach will encourage a more practical approach to problem solving while negating the issue of material selection in the classroom.

"The Gingerbread Man" Unit

Ms Jones class worked on a project for the book "The Gingerbread Man." The "Gingerbread Man" is an alternative unit to the three little pigs, but the story shares a similar issue. The gingerbread man is also escaping from a wolf, like the three little pigs, however the gingerbread man is creating a way to escape from the wolf instead of creating a strong house to keep the wolf out. The problem in the gingerbread man has many more possible solutions, so this allowed for more variety in the student's creations which worked out well for many of the groups. Our group was present for the build stage of this unit and the groups worked surprisingly well. The students had limited materials: lunch trays, paper, tape, cups, string, and popsicle sticks to create a solution that saves the gingerbread man from the wolf. The plans each group had went surprisingly well and there were few issues during the build stage. There was some teamwork issues where the group did not communicate well and needed teacher assistance in order to resolve arguments. However, the students were able to follow through building their plans with little to no help from the teachers. Some groups made bridges and houses, others made rockets and cars. Each design needed to have a place for a cardboard gingerbread man to stay also.

The test for the students' designs is if they are theoretically able to protect the gingerbread man from the wolf. The first grade students all had a wide variety of ideas, and each of them passed because they were able to build a device to keep the gingerbread safe.

The major notes from this unit are how important ample planning and good team communication are. Ms. Jones class had a very smooth building day because the students knew ahead of time what structure they were building and what available resources they would be using. This ran very smooth and every group had a model of their design by the end of the time limit. Previously many groups would struggle with the time limit to build they're designs. Also when the group was arguing, they got very little done in that time so it would be good to intervene early when a group is having a disagreement.

“Three Little Pigs” Unit

On January 25th our team when to the Jamaica Plains school to observe the students in yet another engineering unit. Two of the classes did projects based upon the “Three Little Pigs” short story and the other, as discussed about did a lesson on “The Gingerbread Man”. For the “Three Little Pigs” unit the first graders constructed houses out of a set list of materials including: toothpicks, popsicle sticks, straws, cardboard trays, and tape. The purpose of having a set list of materials was to act as a constraint for the project; which the students would have to work around. After construction, houses were tested using a table fan, which simulated the wolf trying to blow the house down.

Figure 5: Benjamin Seitz studying up on the activity before assisting the students

For Mr. Nunez’ class, on the day that we went in to observe, the students began where they left off the day before which was on the create and execute step. Mr. Nunez decided that he would separate the planning half of the project from the execution half of the project so that students would have ample time to create a detailed plan and design and then enough time to construct the house. In observing the students building our team noticed that some of the students were blowing on their houses to simulate the wind from the fan. This is a sign that the students understood the scope of the project and what their final product needed to do (withstand the wind) and that they could self assess their progress by testing their house part way through the construction. During the recap phase the students were posed questions such as “what did you struggle with?”, “how did the planning process help?”, and “what will you do differently next time?”

In Ms.Coughlan's classroom the students were in the “Test and Revise” stages of their projects. During this time the students each had an opportunity to show the class their final drawing and show off their project. Students spoke about things such as: why they chose their designs, what they struggled with, what they would do differently next time etc. After the showcase of the project the testing began. During testing the students placed a small picture of a pig in their house and air from a blow dryer was applied around the house until the picture of the pig stayed within for long enough or flew out. The testing was very exciting for the students, so exciting that at times it was hard to keep the children's focus. That’s why when we met with the teachers following the activities we all believed that it would be beneficial to break this portion of the project into two groups or two separate time periods.

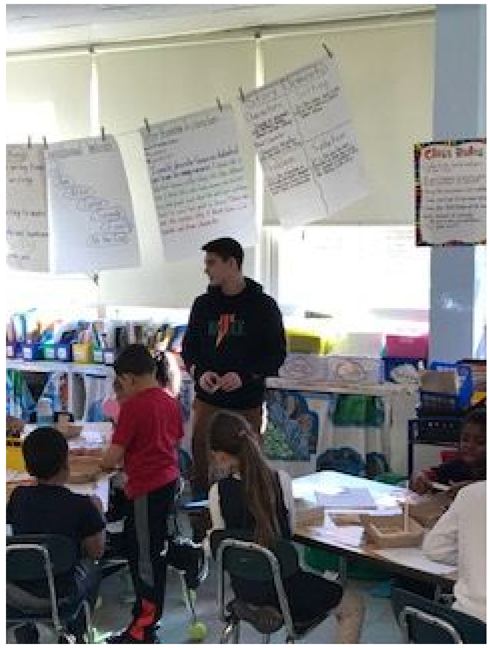


Figure 6: Andrew Ellis teaching the students about engineering!

Results

The rubrics were tested on a sample size of one classroom during our Moon Bear unit. This sample was conducted by filling out a rubric for each and every student based upon each step in the the engineering design process. We then took each individual rubric and combined them all to get a count of how many students fit into each category of excellent, great, good, or needs improvement. Doing so allowed us to identify the areas in which the class struggled most. As seen in the Figure 7 the areas where the class was deficient in included the Plan phase, Create and Execute phase, and the Revise phase.

	Excellent (4/4)	Great (3/4)	Good (2/4)	Needs Improvement (1/4)	N/A	Total
Ask	11	4	3	0	0	18
Imagine	15	3	0	0	0	18
Plan	6	6	5	1	0	18
Create and Execute	4	7	7	0	0	18
Revise	5	5	6	2	0	18

	Excellent (4/4)	Great (3/4)	Good (2/4)	Needs Improvement (1/4)	N/A	Total
Ask	61%	22%	17%	0%	0%	100%
Imagine	83%	17%	0%	0%	0%	100%
Plan	33%	33%	28%	6%	0%	100%
Create and Execute	22%	39%	39%	0%	0%	100%
Revise	28%	28%	33%	11%	0%	100%

Figure 7: Data compiled from rubric after observing class

Speaking to each of the data sets for each phase we can identify how our observations correlate with resulting trends within the data. The reason that not all students were able to score in the top end of the rubric was that some students were not able to fully grasp the concept of shadows and how one could “block” a shadow. Overall, the Imagine phase was successful because students were able to produce solutions, even though they might not have been the most practical in some cases. We identified the problems with the Plan phase being that the students were not often able to create detailed sketches which included labels; many of the students needed reminders or ignored the instructions to include labels in their designs. The phase in which the most deficiencies were present were in the the Create and Execute phase. These shortcomings mainly stemmed from students need to get help in the process of building their actual designs; many students asked for our assistance in making their designs function as they were intended to. For the Revise phase, students primarily struggled to understand the concept of revision. There were some students who tested their design and made revisions based on the suggestions of the instructors, but others got discouraged and did not make the recommended revisions. The reason a few students received a “Needs Improvement” in the Revise phase is the time constraint which could be modified in the future to ensure all students have time to finish their prototypes.

Recommendations

Before starting this project, researching the Jamaica Plain neighborhood was very important. The area has a diverse population, in which many students have English is their second language. Because of this, simple words and patience are necessary when teaching lessons. Visiting the school with the teachers present was the best way to learn about the classroom environment. Also discussion with STEM Education Center is very helpful to prepare WPI students who do not have a strong teaching background for this project. This program reaches out to the pre k-12 community to develop and provide resources that greatly enhanced our lessons. The first time JFK Elementary was visited, an introductory presentation was shown that got the students familiar with the members of the group and allowed us to teach them the ideas behind engineer and foster interest in the field of engineering. This included a Q and A with the students and then they broke up and had a fun project. The student engagement is also higher when that is when the group would come in and assist or present hands on activities. This short fun unit served as a great way to meet the students and test out methods of teaching to figure what work well and what do not.

The unit that our group taught was a great introduction, but that did not cover the Novel Engineering that was the focus of the project. The classroom visits helped understanding of how the projects are ran and this builds up experience teaching and engaging the students. This helped us build a relationship with the students and made our moonbear unit run smoother.

A difficult facet of Novel Engineering is creating a tool that can properly assess the students and show if this program is benefiting the students education. Certain ideas such as the students grading themselves on the projects had great success, while the general rubric for the projects provided data for the students. The general rubric has a downfall because it was to differentiate between the close scores in each category. The standardized rubric data collected was great and showed how many of the students scored in the 3s and 4s. This was also provides a method of quantifying the results and it shows that the students performed very well on the projects by the end of the year. The rubric can be difficult to use because the classes had one teacher and a large class of students. However, it works great for this project because there were five people in our group. An alternative to the rubric was the students self rating their performance in each area of the engineering design process with a smiley face, neutral face, or frown (Appendix B). This system was incorporated on the back of each sheet on the unit packet and the student was required to grade themselves on how they felt they did. There was also a portion for the student to describe why they rated themselves in that manor which produced very valuable qualitative data on students understanding of what was asked, their confidence, and insight into their thinking. An idea the first grade team added to the self evaluation was giving each page of the packet a list of tasks. If the tasks were not all completed for each page the student couldn't do the smiley face. The student self assessment proved to be a valuable tool that charts how each student is performing and the critical thinking skills that are being developed over the course of the year. The self assessments can be saved and compared over the year to chart the progress the student has made in the quantitative data from the rubric.

The moonbear unit excelled engaging the first grade students at JFK elementary; However, the general flow of the project could have been smoother. The greatest difficulty we faced when executing the moon bear unit was creating an understanding of what a shadow was and how it was formed. The most efficient way, we found, to present this to the first graders was through visuals. The visuals were found to be slightly distracting, but effective. In the future it might be more advantageous to have multiple visual representations. This will further aid the students in grasping the concept of a shadow before they begin to build and develop their solutions. Lastly, groups should make more of an effort to communicate with the teachers. If the groups work to develop lesson plans together with the teachers, the group will understand exactly how much preliminary building and design information they need to include in their presentation to the students to help them grasp the concept of a shadow.

References

Alber, R. (2011, May 24). 6 Scaffolding Strategies to Use With Your Students. Retrieved December 18, 2017, from https://www.edutopia.org/blog/scaffolding-lessons-six-strategies-rebecca-alber

Alberta Education. (2007). English as a Second Language Guide to Implementation. Retrieved from http://files.eric.ed.gov/fulltext/ED502914.pdf

APAA. "Education and Socioeconomic Status." *American Psychological Association*, American Psychological Association, www.apa.org/pi/ses/resources/publications/education.aspx.

Booren, L., Vitiello, V., & Downer, J. (2012). Observing differences in preschoolers interactions with teachers, peers, and tasks across classroom activity settings. *Early Educ Dev, 23*(4), 517-538. doi:10.1037/e584752012-003

Boston Public Schools. (2016). Retrieved October 16, 2017, from https://www.bostonpublicschools.org/

Casey, B. (2012, April). STEM Education: Preparing for the Jobs of the Future. Retrieved from https://www.jec.senate.gov/public/_cache/files/6aaa7e1f-9586-47be-82e7-326f47658320/stem-education---preparing-for-the-jobs-of-the-future-.pdf

Collier, S., Burston, B., & Rhodes, A. (2016). Teaching STEM as a Second Language Utilizing SLA to Develop equitable learning for all students. *Journal for Multicultural Education, 10*(3), 257-273. Retrieved from https://search.proquest.com/docview/1823128646/fulltextPDF/5A85B2CFBC55494FPQ/1?accountid=29120.

DeVillar, R. A., Faltis, C. J., & Cummins, J. (1994). *Cultural diversity in schools: from rhetoric to practice*. Albany: State University of New York Press.

Difficulties with Mathematics. (2017). Retrieved October 16, 2017, from http://www.pbs.org/wgbh/misunderstoodminds/mathdiffs.html

[Engineering Design Process] [image]. (n.d.). [Clip Art]. Retrieved from http://www.hand2mind.com/item/engineering-design-process-magnets/8271

Introduction Interview [Personal interview]. (2017, September 14).

Hofmann-von-Baltenau, Andrea. (2016) "The Role of Socioeconomic Status in the EFL/ESL Classroom." https://pedagogsajten.familjenhelsingborg.se/wp-content/uploads/sites/43/2016/12/Hofmann-von-Baltenau_2016.pdf

Kilgo, C. A., Sheets, J. K., & Pascarella, E. T. (2014, June 27). The link between high-impact practices and student learning: some longitudinal evidence. Retrieved October 16, 2017, from https://link.springer.com/article/10.1007/s10734-014-9788-z

Kroeger, J. (2016, August 01). Importance of STEM Education in Elementary School | College of Education - FSU. Retrieved October 16, 2017, from https://education.fsu.edu/importance-stem-education-elementary-school

Massachusetts School and District Profiles. (2016). Retrieved October 16, 2017, from http://profiles.doe.mass.edu/gis/sped_map.aspx?orgcode=06220008&&dropDownOrgCode=2

Massachusetts Tests for Educator Licensure (MTEL). (n.d.). Retrieved October 16, 2017, from http://www.doe.mass.edu/mtel/testrequire.html

M. M. (n.d.). *Demographic and Socio-economic Trends in Boston: What we've learned from the latest Census data* (Rep.). doi:November 29, 2011

Novel Engineering. (n.d.). Boston, MA: Tufts University Center for Engineering Education and Outreach.

Oberoi , S. (2016, June 21). The Economic Impact of Early Exposure to STEM Education. Retrieved October 16, 2017, from https://www.ced.org/blog/entry/the-economic-impa ct-of-early-exposure-to-stem-education

Rinke, C. R., Gladstone-Brown, W., Kinlaw, C. R. and Cappiello, J. (2016), Characterizing STEM Teacher Education: Affordances and Constraints of Explicit STEM Preparation for Elementary Teachers. School Science and Mathematics, 116: 300–309. doi:10.1111/ssm.12185

Rothwell, J. (2016, October 04). The Hidden STEM Economy. Retrieved October 16, 2017, from https://www.brookings.edu/research/the-hidden-stem-economy/

Science, Technology, Engineering and Math: Education for Global Leadership. (2015). Retrieved October 16, 2017, from https://www.ed.gov/stem

The Science, Technology, Engineering, and Math (STEM) Initiative. (2017, July 06). Retrieved October 16, 2017, from https://www.teachforamerica.org/about-us/our-initiatives/science -technology-engineering -and-math-stem-initiative

"Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics" at NAP.edu. (n.d.). Retrieved October 16, 2017, from https://www.nap.edu/read/13158/chapter/3

Teaching Positions. (n.d.). Retrieved October 16, 2017, from https://www.bostonpublicschools.org/Page/201

Tippett, C. D., & Milford, T. M. (2017, March 16). Findings from a Pre-kindergarten Classroom: Making the Case for STEM in Early Childhood Education. Retrieved October 16, 2017, from https://link.springer.com/article/10.1007%2Fs10763-017-9812-8#citeas

Understanding Science, Technology, Engineering, and Math (STEM) Skills. (n.d.). Retrieved October 16, 2017, from https://www.careerwise.mnscu.edu/careers/stemskills.html

U.S Department of Commerce. (2011, August). Women in STEM: A Gender Gap to Innovation. Retrieved from http://www.esa.doc.gov/sites/default/files/womeninstemagaptoinnovation8311.pdf

Yax, C. L. (2013, December 17). Census Explorer. Retrieved October 16, 2017, from https://www.census.gov/censusexplorer/

Yoon, S. Y., Dyehouse, M., Lucietto, A. M., Diefes-Dux, H. A. and Capobianco, B. M. (2014), The Effects of Integrated Science, Technology, and Engineering Education on Elementary Students' Knowledge and Identity Development. Sch Sci Math, 114: 380–391. doi:10.1111/ssm.12090

Appendix

Appendix A (Teacher Rubric)

Goal: Did the student complete each task? Name of Student:_______________

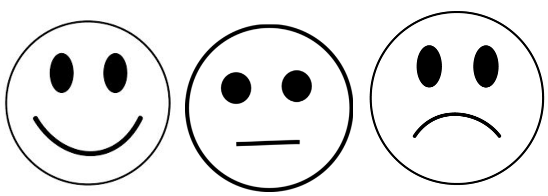
	EXCELLENT 4/4	GREAT 3/4	GOOD 2/4	NEEDS IMPROVEMENT 1/4	N/A	Total
ASK	Was able to successfully identify the problem	Was able to identify most of the problem	Was able to identify the problem with help	Was unable to identify the problem	Not Applicable	/4
IMAGINE	Was able to successfully brainstorm solutions to the problem	Was able to brainstorm some ideas to solve the problem	Was able to brainstorm solutions to the problem with help	Was unable to brainstorm solutions to the problem	Not Applicable	/4
PLAN	Was able to successfully sketch and label their plan	Was able to sketch their idea without labeling	Was able to sketch and label their plan with help	Was unable to sketch and label their plan	Not Applicable	/4
CREATE & EXECUTE	Was able to successfully make a prototype and test it	Was able to was able to make a prototype without testing it	Was able to make a prototype with help	Was unable to make a prototype	Not Applicable	/4

REVISE	Was able to think of new ideas that improve design and solve problem	Was able to think of ideas to improve the design	Was able to think of ideas to to improve the design with help	Was unable to revise their ideas	Not Applicable	/4

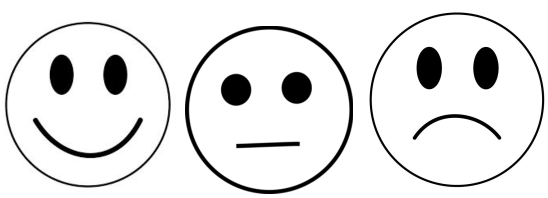
Appendix B (Student Self-Assessment)

How did I do with…

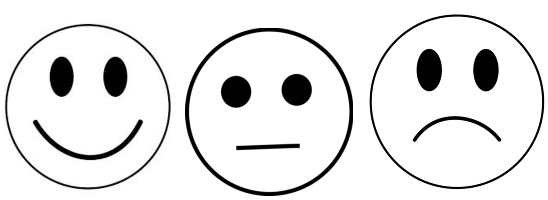
Ask



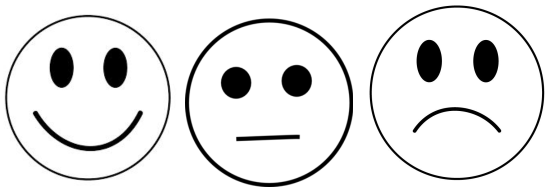
Imagine



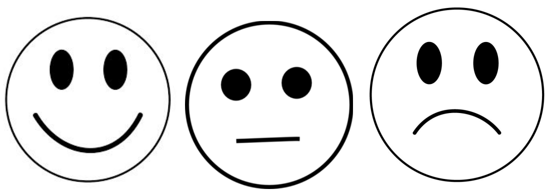
Plan



Create and execute



Revise



Appendix C (Observation Sheet)

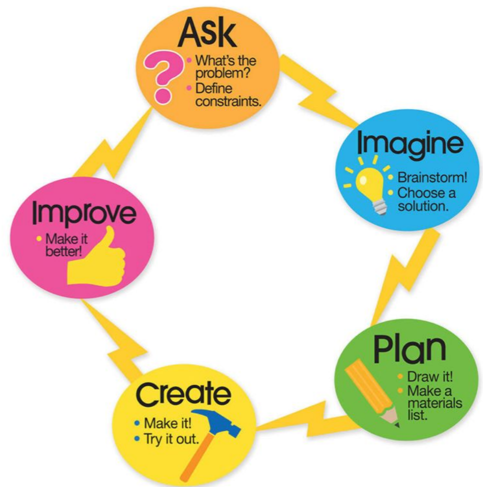
Observations when	Engagement	Teamwork	Cooperation	Creativity
Students are performing Well in these areas				
Students are struggling with these aspects of the visit				

Appendix D (Moonbear's Shadow Unit Packet)

Think Like an Engineer: Moonbear's Shadow

Name: ________________
Partner: ________________

The Engineering Design Process



Ask
- What's the problem?
- Define constraints.

Engineers ASK: What is the problem?

Write and draw a picture of Moonbear's problem:

Imagine
- Brainstorm!
- Choose a solution.

Engineers IMAGINE Possible Solutions

Make a list of possible solutions to fix Moonbear's problem using the following materials:

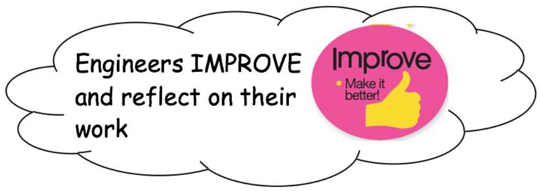
Plan
- Draw it!
- Make a materials list.

Engineers PLAN and Sketch a Solution

Create
- Make it!
- Try it out.

Engineers CREATE and Test a Solution

What was challenging about creating your solution? How did you solve your problem?



Write and draw a picture of what you would do differently

Appendix E (Moonbear's Shadow Unit Presentation)

ASK

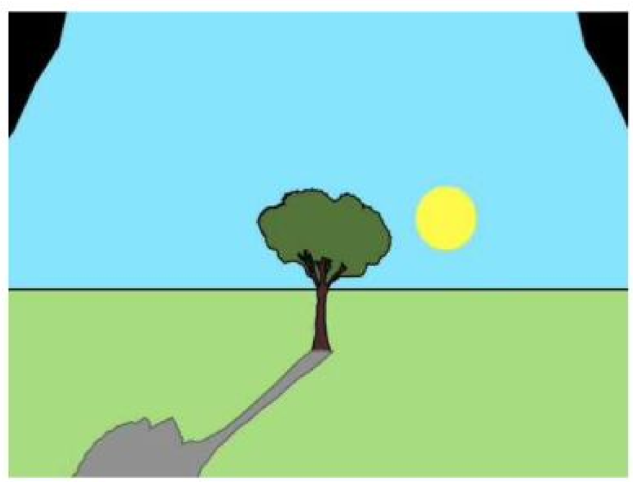
What is the problem in the book Moon Bear's Shadow?

Shadow

How do shadows form?

What things cause a shadow?

A dark area or shape produced by a body coming between rays of light and a surface



IMAGINE

What is a shadow?

PLAN

Let’s draw our ideas!

CREATE & EXECUTE

Time to build!!

We have a light to test your plan!

REVISE

How can we make your plan better?

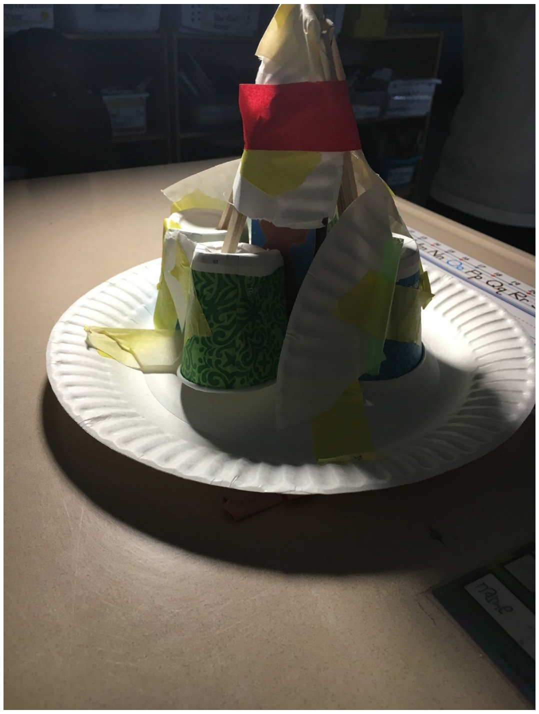
Appendix F (Updated Grading Rubric)

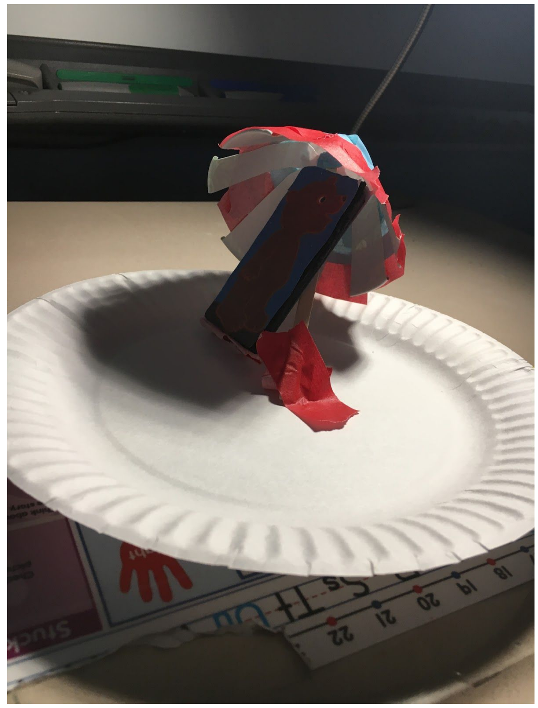
..
Goal: Did the student complete each task?   Name of Student:______________

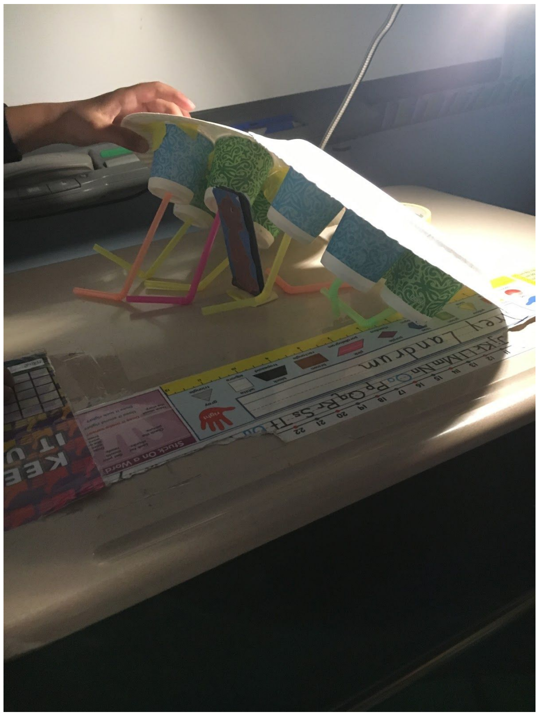
	EXCELLENT 4/4	GREAT 3/4	GOOD 2/4	NEEDS IMPROVEMENT 1/4	N/A	Toal
ASK	Was able to identify the problem	Was able to identify most of the problem	Was able to recognize the problem after being told	Was unable to identify the problem	Not Applicable	/4
IMAGINE	Was able to brainstorm solutions to the problem	Was able to brainstorm ideas to solve the problem with help	Was able to brainstorm solutions to the problem with more help	Was unable to brainstorm solutions to the problem	Not Applicable	/4
PLAN	Was able to successfully sketch and label their plan	Was able to sketch their idea without labeling	Was able to sketch and label their plan with help	Was unable to sketch and label their plan	Not Applicable	/4
CREATE & EXECUTE	Was able to successfully make a prototype and test it	Was able to make a prototype with help	Was able to make a prototype with more help	Was unable to make a prototype	Not Applicable	/4
REVISE	Was able to think of new ideas that improve design and solve problem	Was able to think of ideas to improve the design	Was able to think of ideas to to improve the design with help	Was unable to revise their ideas	Not Applicable	/4

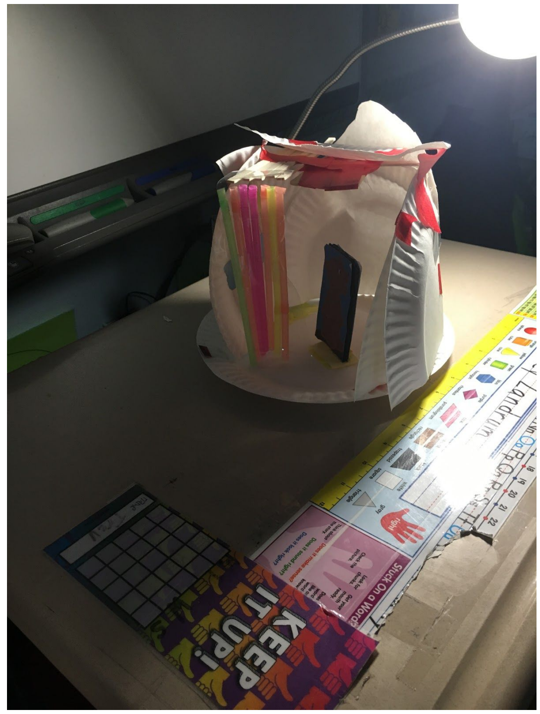
/20

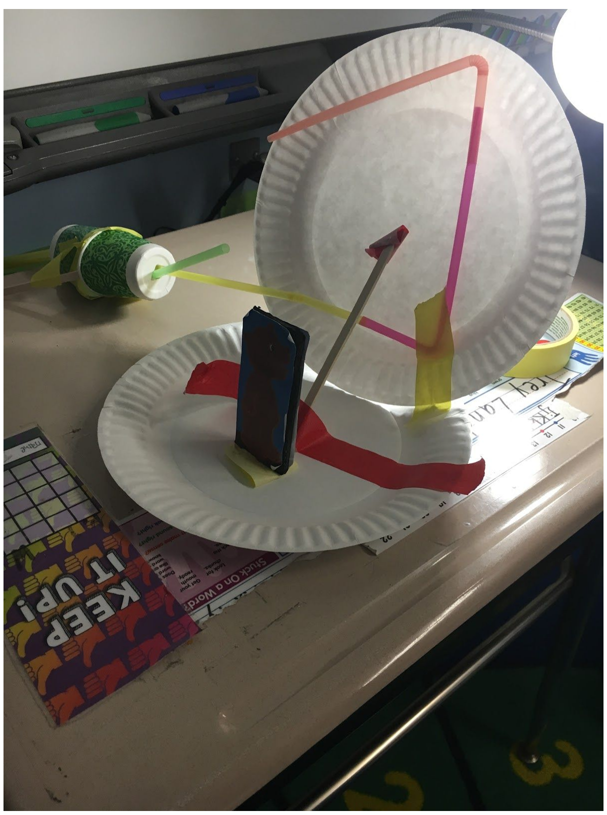
Appendix G (Student Projects)

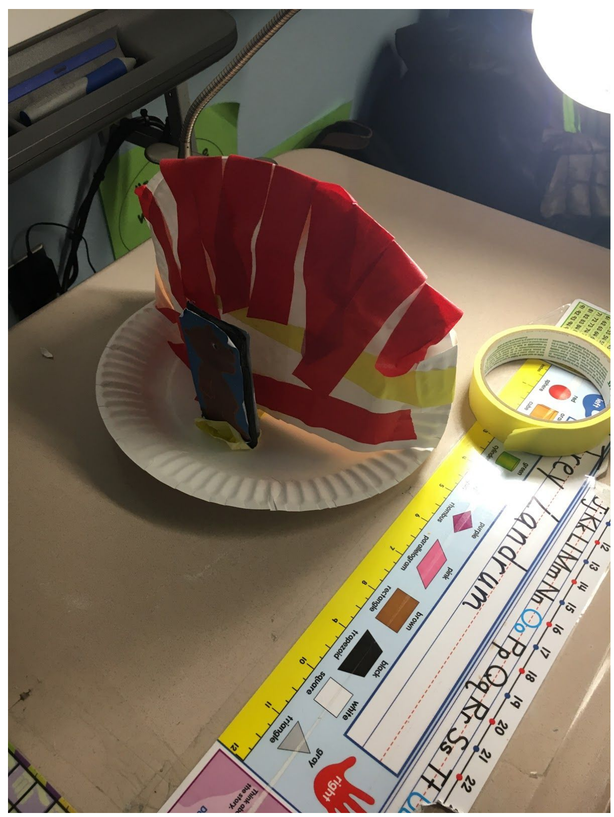


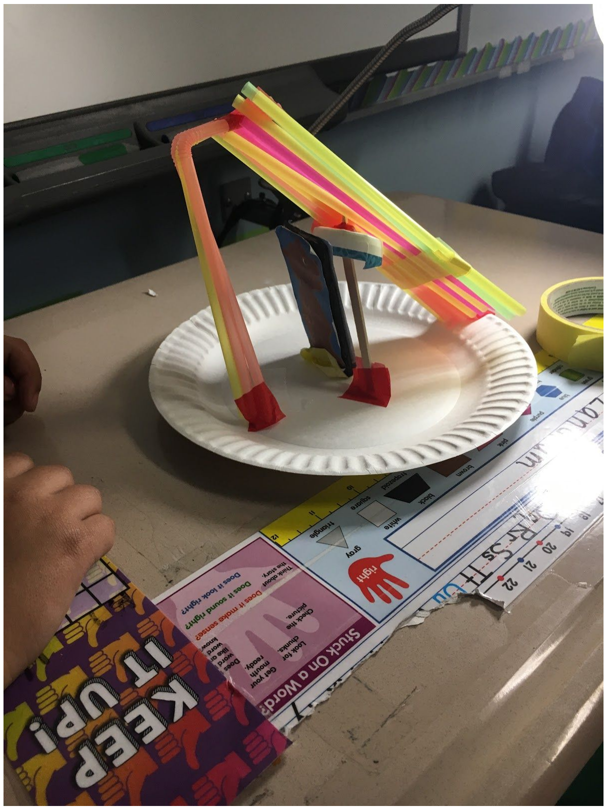


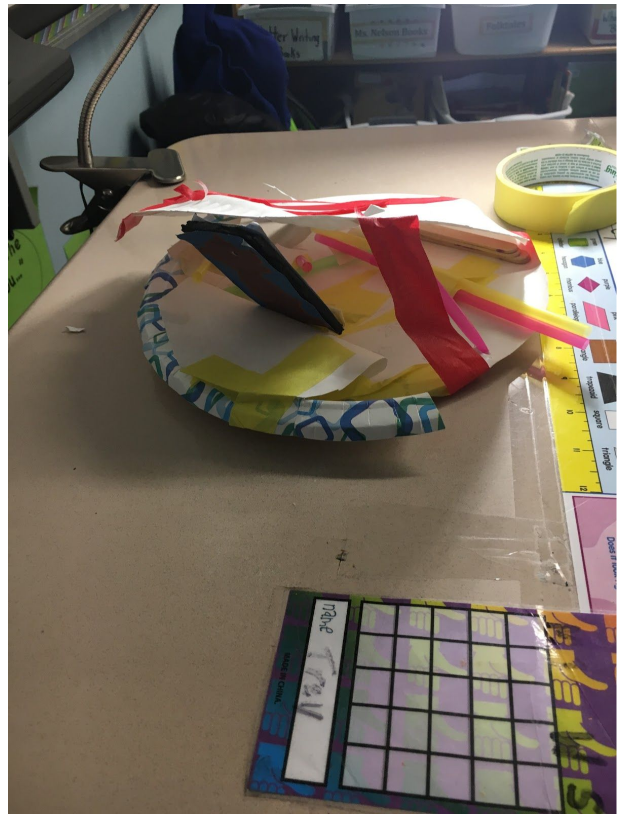



KEEP IT UP!

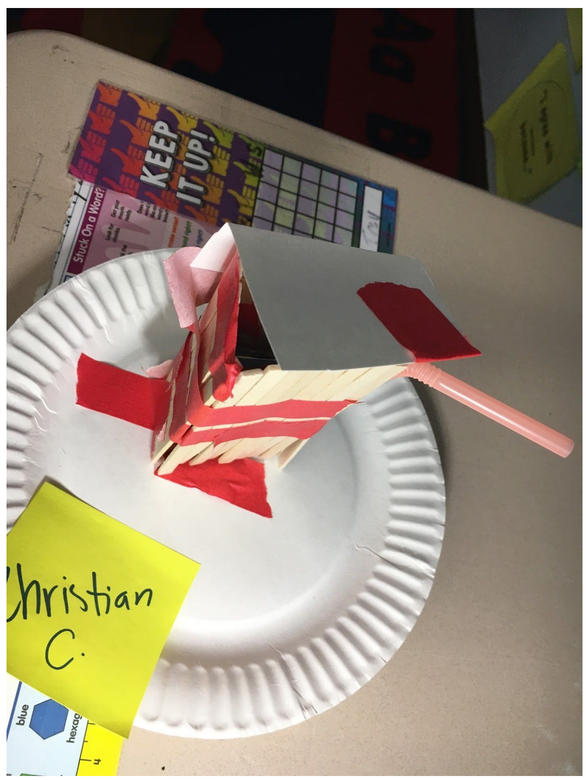

KEEP IT UP!




KEEP IT UP!
Stuck On a Word?




rectangle
parallelogram
rhombus
hexagon
pink


KEEP IT UP!
Stuck On a Word?
Christian C.