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Applying Developmentally Appropriate Engineering Challenges in a First Grade Classroom

Action Research Report
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Applying Developmentally Appropriate Engineering Challenges in a
First Grade Classroom

By Kathleen R. Glick

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St. Catherine University
St. Paul, Minnesota

Advisor: _____

Date: _____

Abstract

The intent of this study was to determine how implementing developmentally appropriate engineering challenges in a first grade classroom could positively impact the students' levels of persistence, creativity and problem-solving. This study was conducted in a first grade classroom with 22 students located in a first-ring suburb of a major metropolitan area in Minnesota. Data collection methods included an engineering survey used to ascertain students' knowledge of engineering and a student school attitude survey, both administered at the beginning and the end of the study, work completion tracked through a grade book, simple formative assessments, and teacher observations. The results showed a positive increase in self-esteem and attitudes towards school, engineering, and reading, as well as an increase in creativity and persistence. Students were actively engaged in the engineering design process. English language learners demonstrated an increased confidence in using their second language. While educators tend to neglect implementing engineering due to lack of training, materials and stresses of standardized testing, engineering design challenges rarely need special equipment and can be a simple extension of current units of study or trade books. In conclusion, young elementary school students can benefit from the inclusion of developmentally appropriate engineering projects.

Applying Developmentally Appropriate Engineering Challenges in a First Grade Classroom

The school where I teach has staff certified as STEM (Science, Technology, Engineering and Math) educators. We have grade level value-added science units, as well as a school-wide initiative involving monarch butterflies. As a STEM school, we work to add engineering activities into the yearly schedule; however, they are not fully integrated into interdisciplinary units, as we are still required to conform to the pacing schedule and prescribed curriculum used by all elementary schools in our district. This limits the available time to dedicate to engineering and STEM principles. Therefore, engineering tends to be an added piece rather than being part of our everyday routine.

My students this year were not actively engaged in learning. They seemed to lack persistence, creativity, and problem-solving skills. Lack of persistence was most evident in morning warm-up work and center activities. In other classrooms, a given assignment could be finished in approximately 15 minutes. My students, however, would either never finish or it would take 45 minutes or more to come close to completing the same assignment. This was not due to lack of ability, because the tasks were well modeled and often were things we consistently did each week. Students wandered the room, visited excessively, and displayed other work avoidance techniques. When we would do a creative writing piece, such as “What should Mrs. Glick dress up like for Halloween?,” my class inquired about the costume I wore the previous year.

After answering their question, it was made clear that they should suggest something different; yet almost every paper came back with what I had worn in the previous year, while students in the classroom next door had a wide range of creative responses and drawings with few duplicates. Even toward the end of the year, students were unable to solve basic problems, including where to turn in papers, how to handle broken pencils, or where they could find available paper.

Bruce Dickinson, singer for Britain's Iron Maiden rock group, is quoted as saying, "Engineering stimulates the mind. Kids get bored easily. They have got to get out and get their hands dirty: make things, dismantle things, fix things. When the schools can offer that, you'll have an engineer for life" (Hotten, 2013). I believe there is truth to his statement. I wondered if we incorporated more engineering opportunities into our units of study, would this help my students be more engaged, persistent, motivated, and creative? Would my students also develop problem-solving skills as a result of the implementation of more engineering projects?

No matter how I organized the classroom environment and centers, many of my students frequently ignored the learning tasks, and either visited or played. When I asked them why, they often replied they could not do the assigned tasks because they either did not understand the procedures or failed to remember the given tasks, even for activities we did weekly. Pictorial sequential instructions seemed ineffective with this group. My students frequently interrupted small group instruction to ask nonessential questions or request a bathroom pass,

despite having established routines and expectations for independently handling such problems. These disruptions became a constant source of frustration to me and distracted those attempting to learn. I knew I needed to motivate my students to become more persistent and independent problem solvers.

Because we are a STEM school, I was encouraged to investigate the benefits of increasing engineering challenges in the classroom. At first, I did not have any idea of how implementing additional engineering challenges would help my students become the motivated and independent problem solvers that they needed to be. As I began my research, it became apparent that there was merit to this approach. Thus, my action research question emerged: To what extent do developmentally appropriate engineering activities provide first grade students with opportunities to demonstrate problem-solving skills, persistence, and creativity?

People may question the appropriateness of teaching engineering to six- and seven-year-old children. To the uninitiated, it may seem that young students are not developmentally ready for the complexity and stresses of the engineering design process. Is engineering a subject valuable enough to address at a time when the primary focus is to take the first grade student, who is essentially a non-reader, to the point of beginning chapter books? An academic leap of this magnitude is not present anywhere else in their elementary career (see Appendix A for a table on reading expectations).

Because six- and seven-year-old children are naturally curious, they are natural engineers and inquisitive scientists, as they are eager to explore their

world and ask an abundance of questions. According to Willingham, elementary students are eager to find solutions for real problems if it has a personal meaning or purpose (2002). Christine Cunningham agrees when she states that children are born engineers—they are fascinated with designing their own creations, from taking things apart to figuring out how things work (2009, p, 11). Simply watch a child build and rebuild when given blocks, and you will see their tireless capacity to create. This can make them ideal candidates to blossom in classrooms that utilize STEM curriculum and strategies.

Ng states that engineers have eight basic characteristics, but four are considered necessary. Those four critical characteristics include an understanding of science, aptitude in math, perseverance, and problem-solving (2011, p. 12). According to Ng, most engineers developed these basic skills as a child when they encountered a challenge or problem and decided to try to conquer it, rather than just accepting the status quo (pgs. 9, 14). While most people have some abilities in all of these characteristics, these skills can be further developed through exposure and practice.

Acquiring these skills when a child is in their early development is critical for motivating and preparing students to be college-ready for the fields of engineering. Christian Schunn articulates the concern that children's lack of exposure to engineering will ultimately result in a shortage of future engineers (2009). Just as students learn the alphabet before they learn to read, and count before they can add, providing young elementary students with opportunities to

experience the engineering process will help give them confidence in developing an aptitude for engineering.

There is an urgent need for students to have STEM skills, especially in our technology driven world. Educators, business leaders, and politicians have begun to articulate the need for upcoming generations to be educated in STEM. According to the STEM Education Coalition's June 2013 summary, "STEM occupations will grow 1.7 times faster than non-STEM occupations over the period from 2008 – 2018." According to the President's Council of Advisors on Science and Technology, "fewer than 40 percent of students who enter college intending to major in a STEM field complete a STEM degree (2012)." Thus, it seems logical that the K-12 educational institutions should support colleges and universities by supplying them with students experienced in STEM skills.

Cunningham points out that engineering is a new subject for most elementary classrooms (2009). Educators across the country are looking at implementing engineering in the elementary schools. Massachusetts and Minnesota were among the first states to develop education standards that include engineering at the elementary level (2009, p. 13). Even as many states begin to incorporate engineering requirements into state standards, teachers struggle to incorporate engineering into the curriculum. Douglas, Iversen and Kalyandurg state teachers believe engineering is important in their classroom, but they lack time, resources, or training to implement engineering (2004 p. 12). Douglas, et al. further report that because high-stakes tests focus primarily on reading, writing, and math, teachers feel that if their states tested for engineering,

they would have more time, resources, and institutional buy-in to implement engineering lessons (p. 13).

Prior to the start of this project, my teaching team and I also struggled to prioritize finding time to implement engineering. When significant blocks of our daily schedule are mandated to be spent teaching math, reading, and writing with a corresponding lesson pacing schedule and administrative directives to follow the teacher's manuals, limited minutes are left for other disciplines. A typical engineering design process from providing background knowledge, problem identification, designing, testing, improving, retesting, and then sharing findings, is not something that is easily accomplished in small periods of time. This is very evident in my school's daily schedule where there is only a total of 20-30 minutes are set aside daily for science, engineering, handwriting and social studies subjects combined. An interdisciplinary approach is needed to truly accomplish the exploration of engineering in an elementary classroom. Douglas, et. al believe that an interdisciplinary approach can help lessons become hands-on and fun for students (2004).

In my many years of teaching, I have observed that more students are becoming stifled by a sense of failure and appear stressed. I believe part of their stress is a result of the demands they sense from teachers adhering to the demands set by the curriculum schedule as well as mandated testing. They know the importance of all the tests they take and want to do their best. Ng also reports teachers she has interviewed notice children today are afraid of failure or not succeeding on their first try (p. 19). This fear of failure can impede creativity.

Thus, the engineering design process may be a vehicle to break this cycle of unease. Engineers do not expect that their first efforts to solve problems will be successful, and are not immobilized by lack of success. When students are allowed to experience opportunities to explore problems through engineering, the process can help students learn that failure is not devastating, but rather is a steppingstone to moving forward.

Description of Research Process

While I planned this action research project to last between four to six weeks, it took longer than anticipated. Many of my students needed basic engineering vocabulary development, as over two-thirds of my class consisted of English language learners. In addition, because we had not attempted many engineering projects this year, they needed some simple engineering activities prior to delving deeper into the final engineering project. In addition, it was “testing season” where schedules are altered, and the end of the year was approaching with guests, assemblies, field days, field trips, etc. that impacted our daily schedules. As a result, from start to finish, my project lasted eight weeks. Typically, we worked on engineering two days a week in a larger block of time, one to two hours per day, and sprinkled in short supplementary activities throughout the remainder of the week.

My students completed two surveys. An online form was used (see Appendix B), where the aim was to understand any misconceptions students may have on the design process and the work engineers do. In addition, I wanted to see how they self-evaluated their problem-solving skills. The other

paper-pencil survey (see Appendix C) was a simple attitude survey regarding all aspects of school. Both of these surveys were again administered at the end of the project to determine student growth.

After the initial survey, we gathered as a class and did a tree map where the main topic was “Engineers.” I asked students what engineers are, what they can do, and what they use in their jobs. Every student was asked to provide at least one answer. Every answer was recorded without comments, even if it was a misconception. Only one student was unable to share an idea. I believe that his lack of English language skills impacted his ability to share.

The next week during read-aloud time, I read one or two stories (see Appendix D for the list of trade books I used during this project) which had an engineering theme. In subsequent weeks, we discussed the aspects of engineering, and often there was time afterward for students to express their creativity by doing a quick write or drawing based on the story (see Appendices E and F). When our reading curriculum had a story of gliders and planes, I read two other stories where the main characters were young children with curious, adventurous minds that built planes. We then added a short engineering challenge where students built a glider using only four pieces of tape, two pieces of paper, and a straw. The students then tested their gliders and tried to make it better. Students recorded the entire engineering process on their Student Engineering Design form (see Appendix G) while I recorded observations of their comments and actions on my daily reflection sheet (see Appendix H).

There were several areas of this project that could be improved in the future. On the Student Engineering Design form (Appendix G), I would pre-fill in some of the areas, such as the problem statement or the materials box, so that there is a limited amount of writing students needed to do, as many first grade students still struggle with simple letter formation. In addition, it was necessary to model how to illustrate a three dimensional object. Even though students were able to roll paper up, creating the hoops was difficult for many students as well as attaching them to the straw. There were many comments from students saying, "I can't do this." But with encouragement, as well as restraining my temptation to help students too much, they were able to make a loop and attach it to the straw. It was very hard for the students to determine why some gliders flew a short distance while others went a much longer distance. Because of that, the section entitled "I Learned" was particularly difficult for students to complete. As such, we changed the box title to "What Happened," which made it easier for students to complete that section of the form.

At the beginning of May, we were in the middle of a unit of study about rocks and earth materials. Students were asked to bring in a rock that we decorated to become their pet rock. They named their rocks and wrote stories and poems about them. Our reading curriculum was simultaneously talking about animal habitats. Thus, students were given the opportunity to engineer a habitat individually for their pet rock.

As a culminating engineering project for this science unit, my students did a "Float Your Boat" challenge. They independently created clay boats that not

only were required to float for more than five seconds, they also had to hold as many pennies as possible. The next day, students were asked to try to improve their design and results.

I continued to read both fiction and nonfiction books to students with engineering themes, as well as books that demonstrated persistence. I began to informally observe their ability to work for longer periods of time independently while in math and reading centers to determine if their exposure to engineering had improved their persistence and problem-solving skills. I also analyzed how their work completion rate changed at a time of year when students typically start getting lax or bored with schoolwork. I recorded not only their ability to complete assigned tasks, but the quality of those assignments in my grade book (see Appendix I).

Finally, in late May, we began the culminating project. Students had been studying animal habitats and were asked to bring a small stuffed animal from home. This created an unexpected problem that delayed the project again. I discovered that approximately half of my students did not own any stuffed animals, perhaps due to socio-economic or cultural reasons. One of my teaching partners brought in some animals from her home to solve this problem. Once everyone had a stuffed animal, they were challenged to build a realistic habitat for their animal. They were not to think of it as a toy, but rather the wild animal it represented. This limitation was very difficult for students, especially those who owned their stuffed animal. Perhaps this was because students are emotionally invested in their toys and use them for imaginative play rather than a component

of a project. Finally, all students had to share a limited supply of materials.

Because I did not think to put limits on each kind of material, some students used excessive amounts, which resulted in negative comments from their peers.

The next day, after they shared their projects, I grouped the students into small groups of two to four students. Most groups had three students. Here, the students needed to create a collaborative habitat that fit all their animals. They needed to decide what parts of their individual habitats could be used in a larger common habitat. Due to a shortage in supplies, students had a limit on new materials available for the building process. The habitat needed to have space for all the animals, as well as all of the necessary aspects to keep their animals healthy. They were to respect all ideas, and everyone was equally responsible for working towards the end goal of creating a common habitat.

Finally, during the first week of June, we revisited the initial surveys (see Appendices B and C) to reflect on what they had learned. As a final assessment, students were tested on their knowledge of the engineering design process. They were given the same picture design cycle (see Appendix J) that we used during this project. Students then labeled the steps in the process using the provided word bank. In addition, students completed their own “Engineers are/can/use” tree maps (see Appendix K). After all students had completed their independent tree maps, we revisited the original class tree map to add new concepts, as well as to delete any inaccurate ideas they had presented earlier.

Data Analysis

Many methods of data collection were implemented during this action research project. The first was a school attitude survey (Appendix C) administered at the beginning and the end of the project. My hope was to specifically see improvement in students' attitudes towards school and engineering, as well as increases in positive attitudes towards literacy and math. Much of a first grader's day is spent doing literacy and math activities, many independently at centers while I am working with small groups. I surmised that my students lacked the ability to stay focused or be persistent in centers potentially because they lacked confidence or interest in reading and math. The survey was designed with emoticons in every box because at the end of every math unit they were asked to self-assess their math skills by marking one box next to each listed skill. Students frequently became confused on how to mark boxes and as such, they would mark every box in a row. I thought having an emoticon in every box would limit the confusion as to what the boxes signify.

As I compared the results of the school attitude survey from April to June, I noticed the areas that demonstrated the highest level of increased positivity were student's own self-esteem, school in general, engineering, reading, and physical education. 55% of the respondents to this survey thought engineering was "awesome" in April, compared to 82% at the completion of the action research project. When you include students who responded that engineering is "just fine," that percentage increases to 100% of those involved in this project, leaving no doubt engineering had become the students' favorite thing to do at

school.

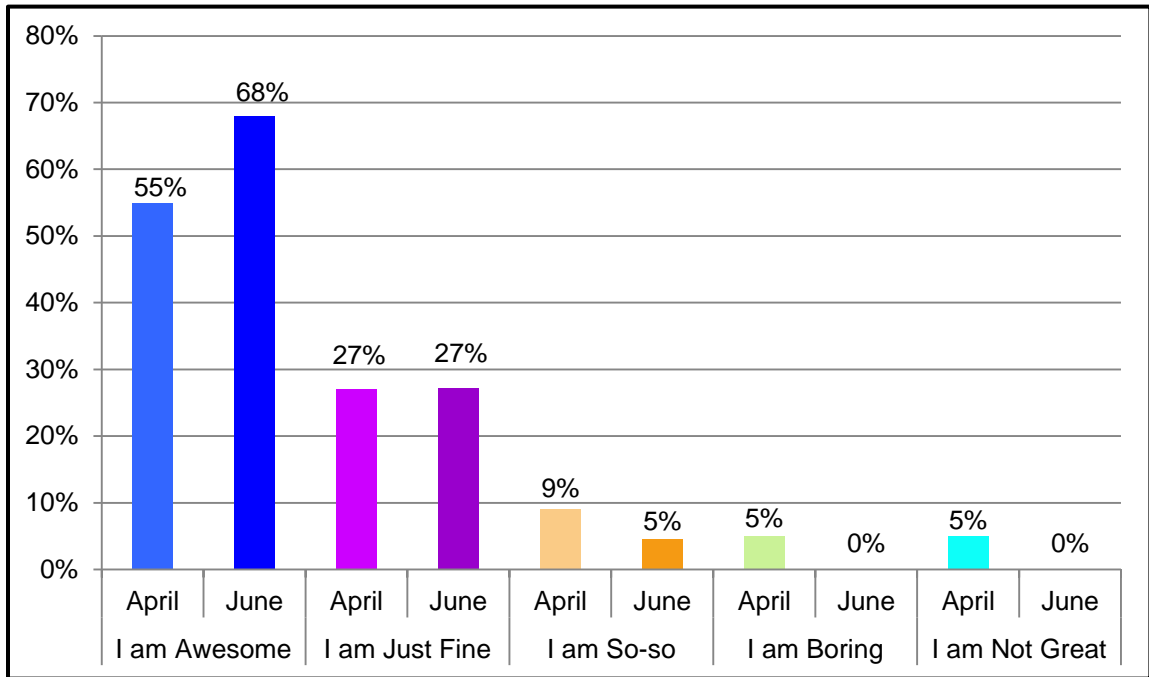


Figure 1: Self-Esteem Attitude Survey. This figure shows the changes in students' perceptions of themselves during this study.

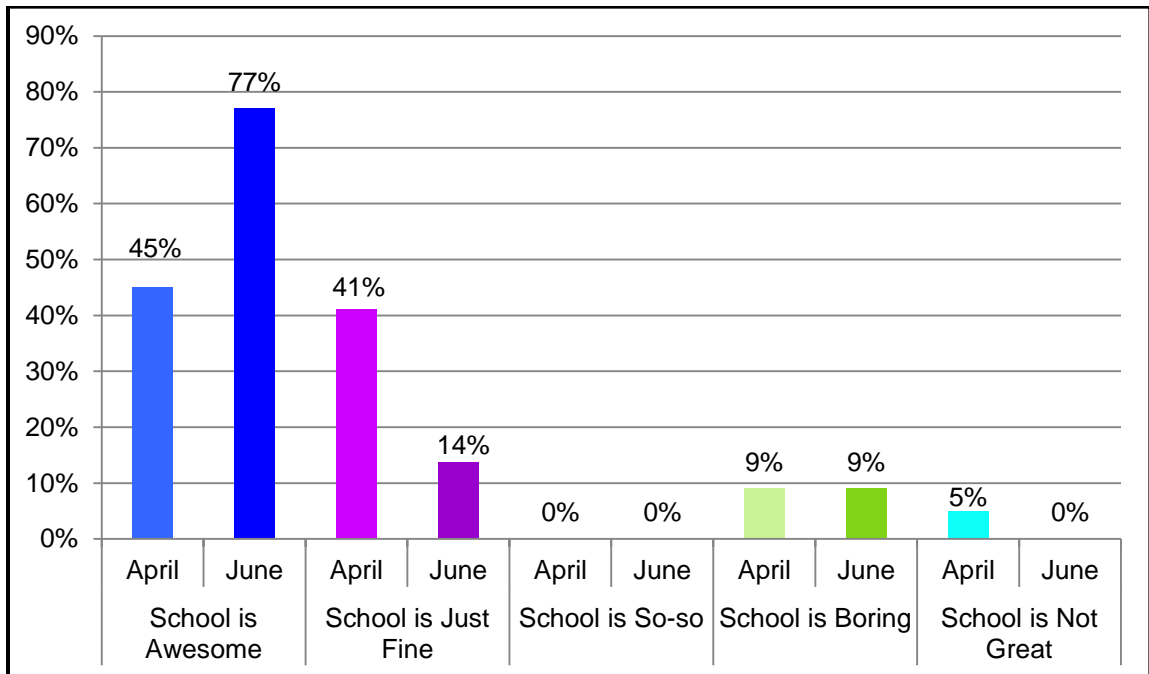


Figure 2: School Attitudes Survey. This figure shows the changes in students' attitudes towards school during this study.

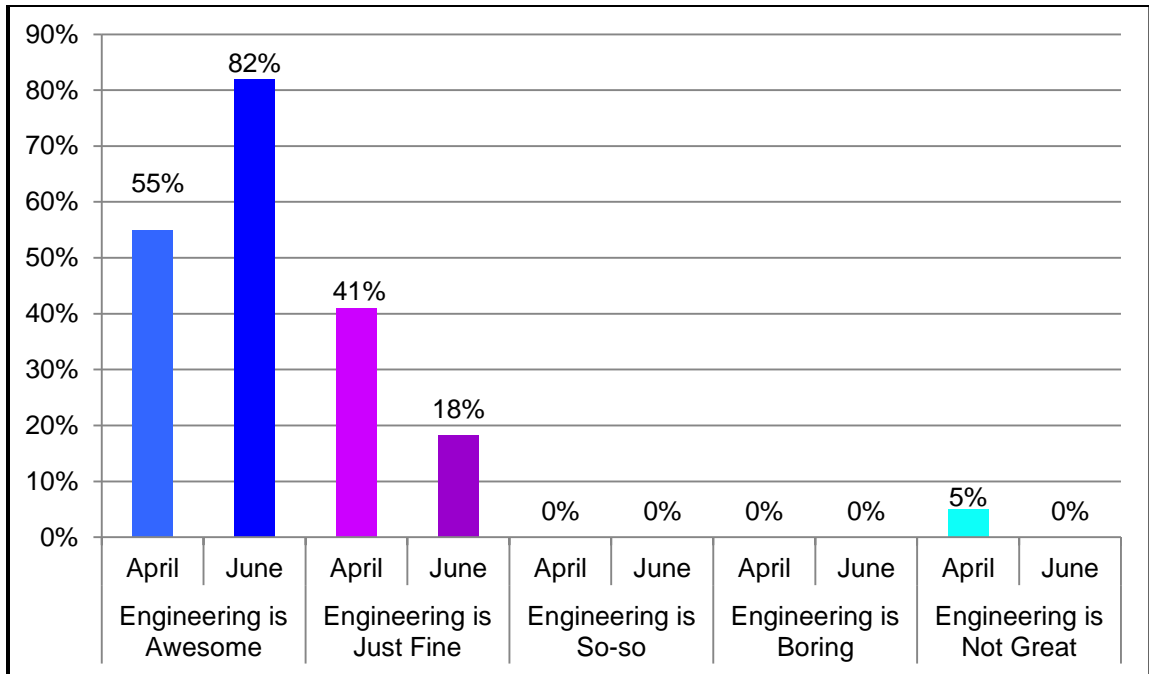


Figure 3: Engineering Attitudes Survey. This figure shows the changes in students' attitudes towards engineering during this study.

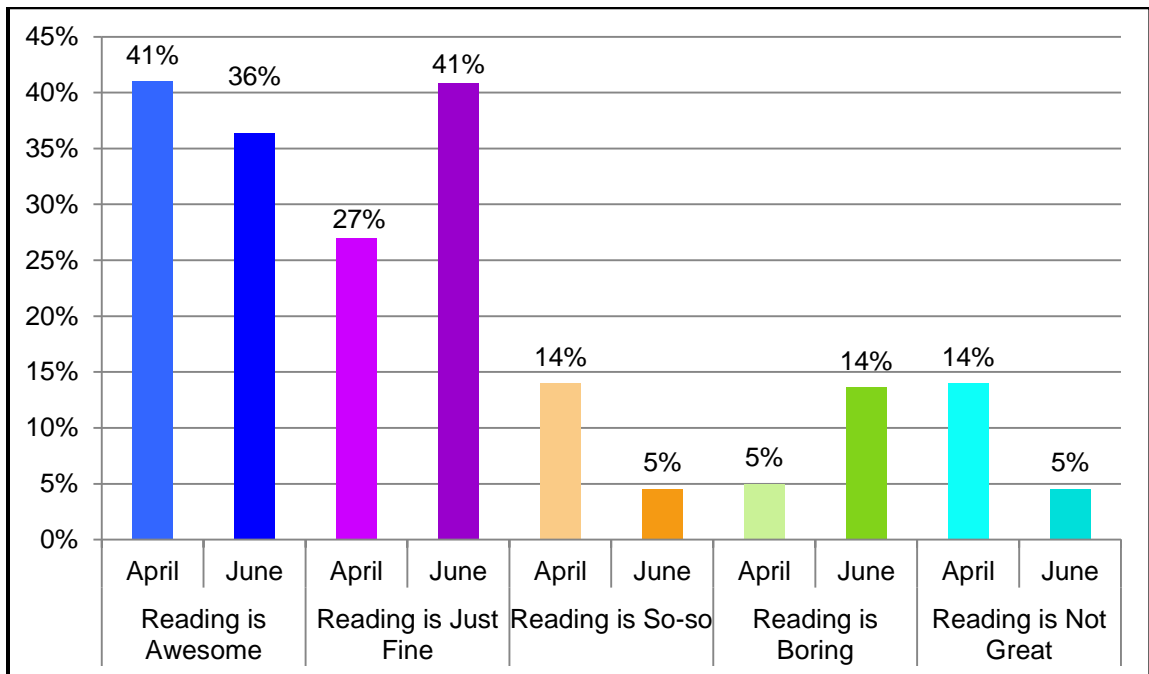


Figure 4: Reading Attitudes Survey. This figure shows the changes in students' attitudes towards reading during this study.

Math and social studies showed the largest drops in positive attitudes. Much of the final math units of the year are meant to serve as an introduction to second grade math skills. For first grade students who had not yet fully mastered first grade skills, increasing the difficulty of math caused confusion and frustration and, may have contributed to the decrease in positive attitudes towards math. Social studies may have dropped simply because social studies units were not taught during the action research project. Students may have been unsure what was meant by “social studies,” and as such their attitudes may have dropped.

A Google form was also used at the beginning and the end of this project to help determine students' knowledge about the work and skills of engineers, as well as the engineering design process (Appendix B). I discovered that while I attempted to write the survey in a manner that would not lead students to think there was a correct answer, it became a data collection measure that was not highly useful. Before starting this project, I suspected that the students did not understand what an engineer does for his/her job, so one of the questions addressed that specifically. In April, only 13% of my students thought that an engineer solves problems, while 25% thought an engineer was a person who cleans buildings, and 29% thought an engineer fixes cars. In June, 42% of the students understood that engineers solve problems. Those that thought engineers fix cars had dropped to 17%. It appears that the same 25% still thought engineers clean buildings. This may be because we call the people who clean our school, engineers, rather than custodians.

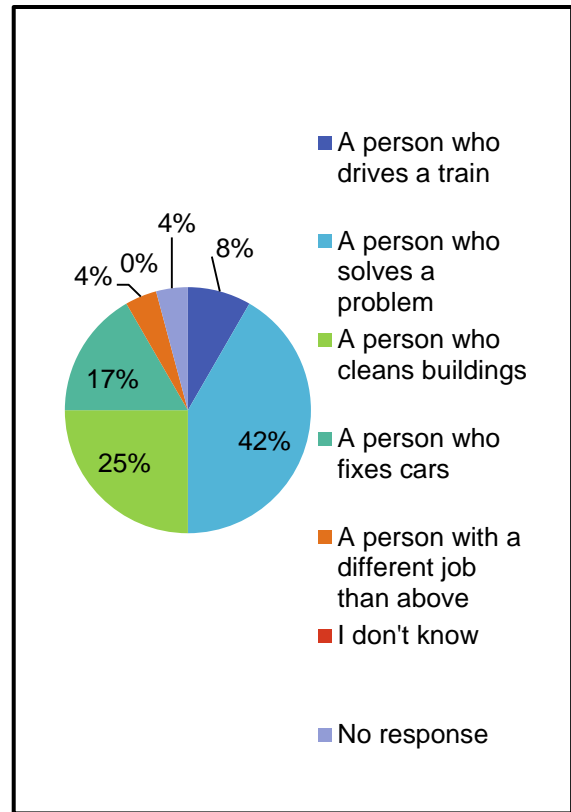
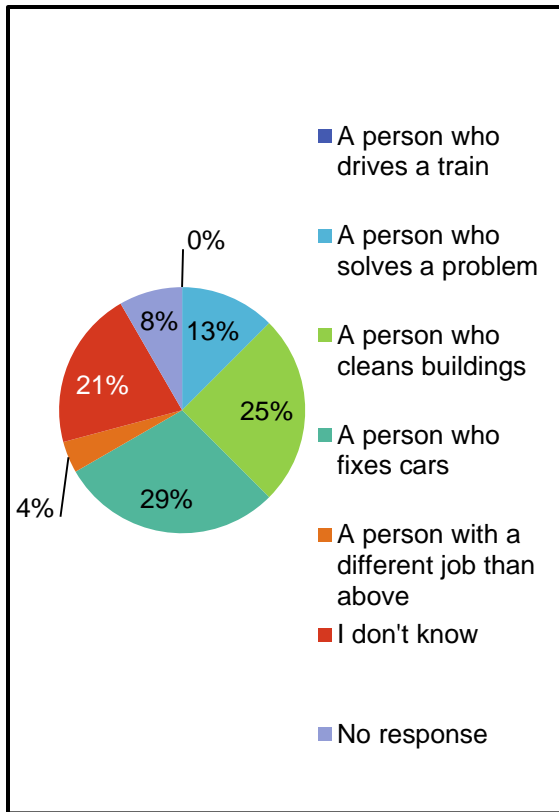


Figure 5 (Left): April's First Grade Engineering Form Question 9 summary. This figure shows students' perceptions of engineers' when asked in April.

Figure 5 (Right): June's First Grade Engineering Form Question 9 summary. This figure shows students' perceptions of engineers' when asked in June.

Prior to starting this action research project, I wondered if my students' low work completion rate had anything to do with the fact that they felt that their work must be completely finished or perfect. There were several students whose work regularly was found in either the recycling bin or the wastebaskets or buried in their desks. One of the questions on the First Grade Engineering survey asked if it was ok to create or build something that doesn't work. In April, only 54% said that it was permissible to build something that doesn't work. In June, that rate had increased to 71%. As I worked on this project, there were a few times I noticed students were encouraging their peers to "just try" when they were

struggling. Those types of comments were not previously heard earlier in the year. It was gratifying to see students supporting one another. While I saw anecdotal evidence that my students viewed problem-solving as an important skill in responding to the Engineering Survey in June, the same percentage of students, although different students, like problem-solving as what was reported in April. However, more students reported that they “sometimes” liked problem-solving.

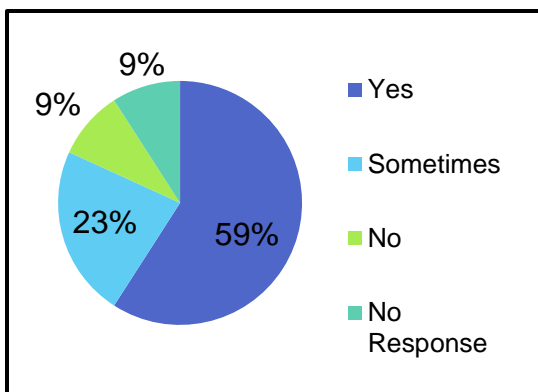


Figure 6 (Left): First Grade Engineering Survey Question 5 - April. This figure reflects students' responses to the question "Do you like to solve problems?"

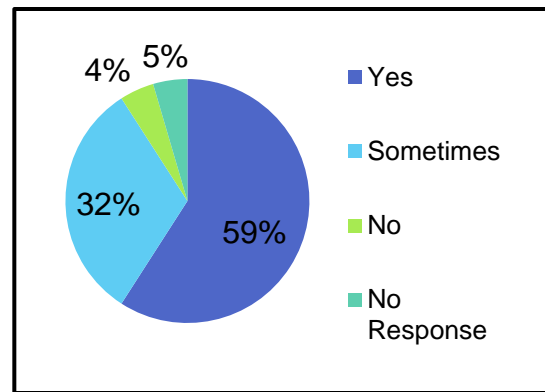


Figure 6 (Right): First Grade Engineering Survey Question 5 - June. This figure reflects students' responses to the question "Do you like to solve problems?"

To clarify students' abilities to be persistent and use their problem-solving skills, I relied on the classroom assignment portion of my grade book (see Appendix I). If an assignment was going in my grade book, it was something that had been practiced previously as a whole group or modeled by me. Directions were read and discussed thoroughly. Students were encouraged to use tools around the room to help them complete their work. These tools may have included word walls, number grids, counters, anchor charts, friends, etc. Thus, if

students completed the work in a satisfactory manner, they were showing both persistence to complete the task in a given time frame and problem-solving skills to complete assignments in multiple centers that day. Students who turned work in that had many errors demonstrated some semblance of persistence, but lacked problem-solving skills. Those that never turned in their work or turned in work that was excessively incomplete showed a lack of both persistence and problem-solving skills.

As I began planning for this project, I started keeping track of all assignments in math and reading in my grade book. Earlier in the year, I had only done a random sampling of math, reading and writing assignments. I had not recorded any science or engineering assignments in the grade book as it was not mandated for report cards. This is why *Figure 7* does not have any comparative data for science.

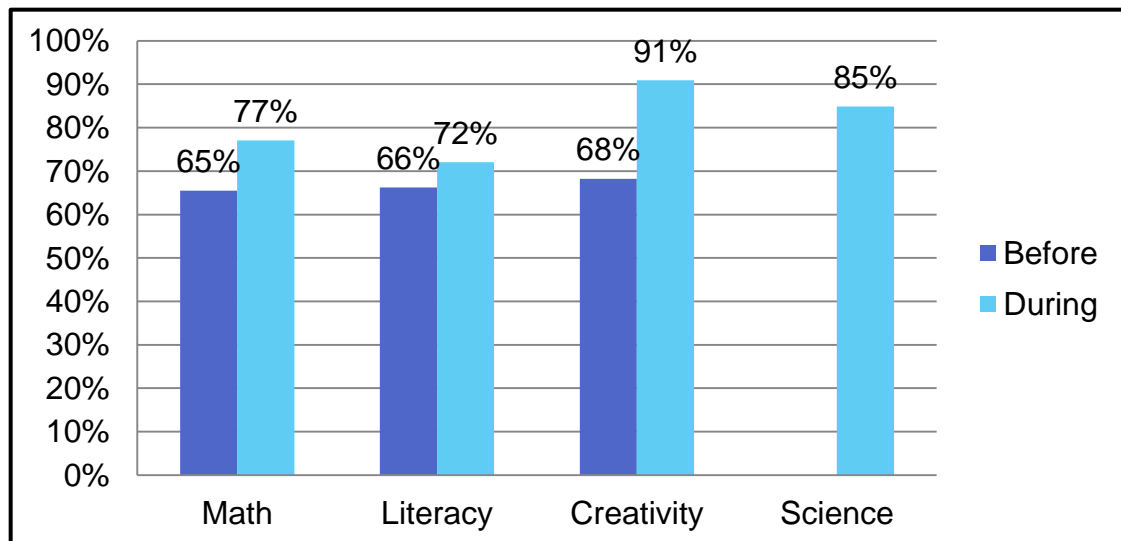


Figure 7: Grade book - Persistence Data. This figure illustrates the changes in persistence level during the course of this study.

Figure 7 shows that students' persistence level increased in all areas with creativity exhibiting a 23% growth while persistence in literacy there was a 6% growth.

As I looked closer at the data, my students who either were diagnosed with attention issues or exhibited noticeable signs of distractibility continued displaying lack of persistence throughout the entire year. They did, however, show an increase in completing assignments involving creativity. Persistence in creativity was measured by the originality of their writings and drawings from trade book extensions (see Appendixes E and F) compared to similar assignments done earlier in the year and kept in their student portfolio.

In trying to analyze students' growth in problem-solving skills, I once again turned to my gradebook. Again, the assignments recorded were tasks students were familiar with, were modeled, and had ample tools such as word walls and anchor charts available around the room for students to use if they were unsure of what to do or how complete the task. The results once again showed a gain in all areas and once again, creativity grew the most, while gains in reading were more subtle.

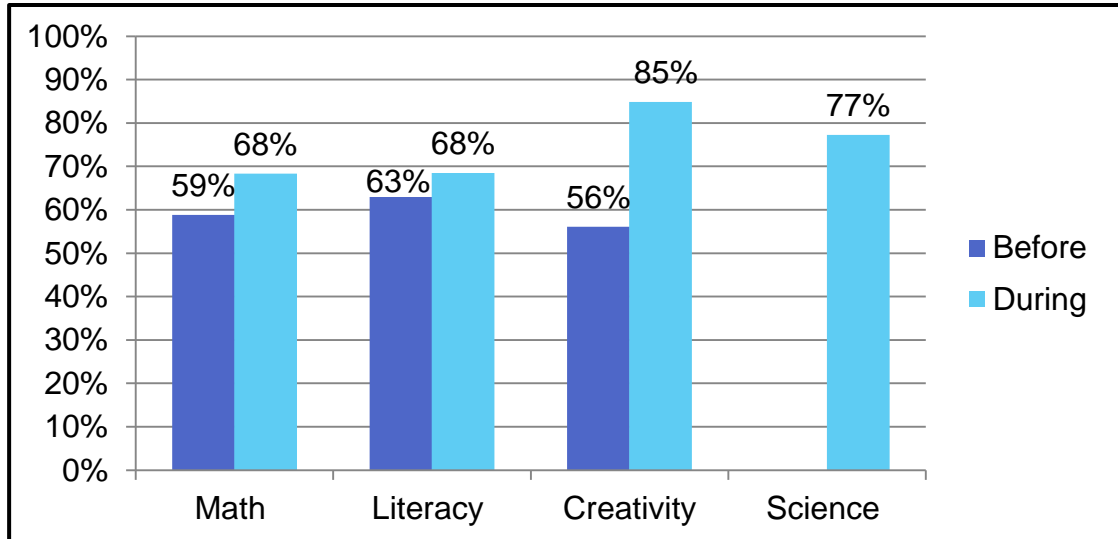


Figure 8: Grade Book - Problem-solving Data. This figure illustrates the changes in students' ability to use their problem-solving skills during the course of this study.

During this study, students were asked to respond creatively to three different trade books. They were told they were not allowed to copy any of the drawings or writings found in the story they had just heard, as this was like stealing the ideas of the author. Students were given time to contemplate what they might draw or write and needed to tell me their idea before returning to their desk to do the work. While at their desks, they were reminded that they needed to be original in their drawings and writings and should not be copying their neighbor.

Two of the books, *It's Not a Stick* and *It's Not a Box* by Antoinette Portis, seemed to be easier for students to exhibit their creativity. Initially, I believe this was because lines and squares were familiar shapes for. However, in discussions with colleagues, I was reminded that although these books were originally part of the first grade Technology unit, several kindergarten teachers

had read the books and did the activity with their students the previous year. As such, the positive increase in creativity for these books may have been skewed slightly by repetition. *The Shape of Things* by Dayle Ann Dodds was more difficult because they were just learning shapes such as rhombus, hexagons and trapezoids.

Table 1: Creative Extensions to Read Aloud Books

Book	Original Ideas	Plagiarized from book	Copying Neighbors
<i>Students</i>			
<i>It's Not a Stick</i>	15	0	2
<i>It's Not a Box</i>	18	0	3
<i>The Shape of Things</i>	13	4	3

Table 1 Source: Gradebook (See Appendix I).

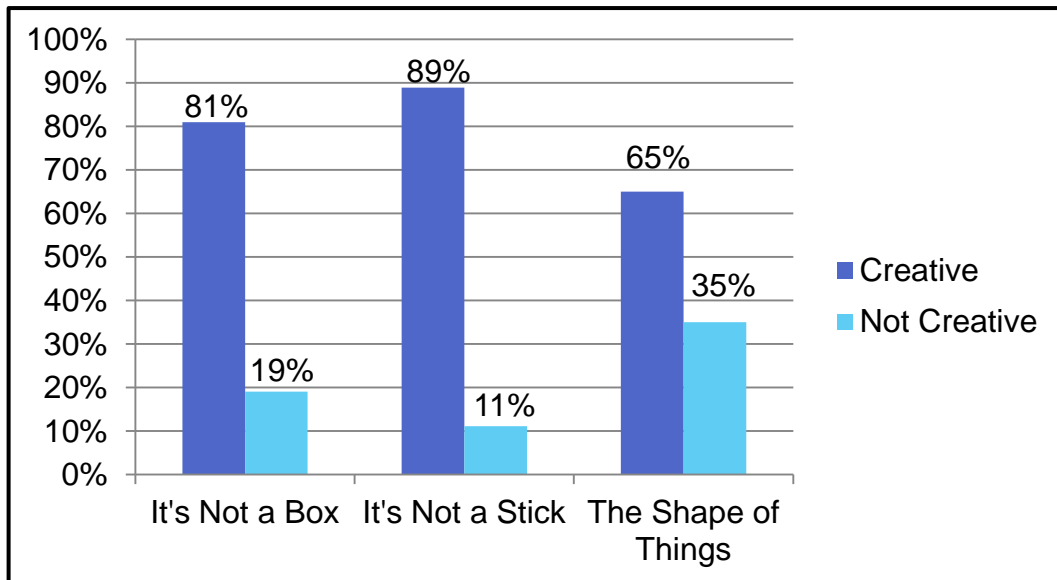


Figure 9: Grade book - Creativity Comparison Data. This figure shows the percent of students who produced original work versus those whose work was the same as their neighbors.

On the days students were actively engaged in engineering challenges, I tried my best to record anecdotal information on my daily reflection form (see Appendix H). This was not an easy task as students were situated throughout the entire room, and many had questions or needed assistance, so I found I did not have the luxury to sit back and observe all the minute details found in the business of the room. To help with data collection, I would take photos and short video clips of the action and final products to supplement reflections in my journal.

For the Hoop Glider Engineering Challenge, students needed to figure out how to attach the paper hoops and where the best place would be to put the hoops on the straw so that it would glide the farthest. Some self-talk I heard that day included:

“Will this work? I don’t know, ‘cause I’ve never done this before.”

“Those hoops blocked the wind.”

“I noticed when this one (the smaller hoop) is on this end, it go farther.”

“I’ll try this.”

“This is not going to work.”

From the comments I was able to record, approximately 71% were positive in nature and 28% were negative. Approximately 53% of the students who completed this challenge for the second time, were able to improve their glider so it flew for a longer distance. The average distance flown on the first attempt was 71 inches, and for the second attempt 76 inches. The gliders’ flying ranged between 34 inches and 182 inches.

Prior to starting the Clay Boat Engineering Challenge, we looked at photos of various boat designs as a way to build background knowledge. Students started off being confident because they had made a clay boat the prior year that needed to float. This year, the boat not only had to float, but it needed to hold pennies. Students were then given a piece of clay to work until it was flexible, and then were given seven minutes to form their boats. Many were done within just a few minutes and could not be encouraged to keep working. It was obvious that even though the STEM Rules (see Appendix L) had previously been taught, they did not understand that engineers keep working and do not say, “I’m done!”

When we tested the clay boats and pennies for the first time, only 50% were able to float and hold pennies. The record number of pennies held by a clay boat on the first attempt was 18 pennies. When the student whose boat held 18 pennies was asked why his boat was the most successful, he stated “I just kept pressing the bottom till time was up” in order to make a big flat bottom “so it would float.”



Figure 10: Picture of the student's boat that held the most pennies.

Interestingly, when this same student did the “make it better” portion for the second attempt, his boat immediately sank. In fact, on the second attempt only 35% of students were successful in creating a boat that floated and could hold pennies. One student’s second attempt held 29 pennies, which is 21 more pennies than the first attempt. Seven

out of twenty students, or 35%, were unsuccessful in creating a boat that floated either time.

When we discussed what students had learned from this activity, many responded that they forgot to continue to work on the challenge until time was up. We revisited our engineering rules (see Appendix L). Several asked for a third opportunity to try again, but unfortunately scheduling would not permit a third attempt. However, based on the discussion the students had, I believe they may have been more successful.

The Pet Rock Habitat was the next challenge for students. Students had decorated their pet rocks and were given the same size box as a starting point for building their habitat. They were told that their rock needed a safe place to rest. Time limits were imposed and materials were limited. Many exhibited great creativity. One student who has many issues with reading, writing and math, made a soft bed behind a waterfall for his pet rock to rest. This student beamed with pride when others made positive comments on his rock habitat. Another ELL student who rarely spoke in class because he lacked the English skills was proud to show off the forest where his pet rock lived. I was excited to see him be able to communicate orally about his project. Another student made an elaborate swamp for the pet rock. Another made a cave, and one put the pet rock in the Arctic with a hidden snowman, another was under the sea, and another made a snow cloud that hung over her pet rock (see Appendix M for sample pictures). Only 18% of students participating in this challenge did not create a recognizable habitat and were not able to “give a tour” around their pet

rock's habitat. Students seemed to enjoy this project immensely. There did not seem to be any problems that the students could not overcome.

Our last two engineering design challenges involved engineering a habitat for their stuffed animal. They needed to ensure that there was a water source, a food source and safe resting place for their pet. Students were instructed to pretend that the animal they were working with was a wild animal, not a pet and the habitat they were to construct needed to be as realistic as possible, based on what we had learned about habitats. Again, time limits were put in place.

When this challenge was done, students exhibited their ability to fantasize. Most habitats contained things that would not be useful to wild animals or found in nature, such as a hammock, pool, trampoline, or food bowl (see Appendix N for sample pictures). Because I did not put limits on how many materials the students could use, there were many issues involving the fairness of sharing materials. I also had not put in a limit as to the size of the habitat; thus, some students' habitats were so large they became a challenge to move and store. Clean up from this project was also a big issue as only a few students showed responsibility toward cleaning the room, despite repeated requests.

The final culminating project was the Cooperative Animal Habitat. Students were placed in groups of two to four students based on the animals' habitats. Prior to beginning this project, they were given time to share what they felt was the most important feature of their individual animal habitats, and as such, should be included in the group's habitat. They were asked to create a drawing of what their final project would look. Because of the lack of limits put on

the designing of the individual pet habitats, building materials for the cooperative project were significantly depleted. Thus, students were encouraged to recycle materials and portions of their individual habitats for use in the group habitat. Time limits were imposed, along with material and final space limitations.

Although groups were given instruction that everyone in the group needed to work together to create one larger habitat, one group could not collaboratively create a habitat. They just improved their individual habitats and placed them in the general vicinity of each other's projects. They were observed working continually with their backs to each other despite repeated reminders to work together cooperatively. Another group had a "big boss" and all other members of his group *had* to do as he directed and were not allowed to incorporate their ideas into the project. Many groups struggled with listening to others' ideas and working together to accomplish the task. At least one group, had members sitting on the edge of their work space not being included or contributing. Some groups worked well together. The groups that worked well together seemed to divide up the workload: one student worked on the water requirement, another the resting area and the others obtained materials or made suggestions for improvement. All groups worked the entire time period.

I recorded in my journal as many comments as I could during the building period for this project. When I grouped comments through the lens of positivity or negativity, 71% of the comments I was able to record were positive in nature. Sample positive comments that showed my students were able to work together and problem-solve included:

“Cool idea!”

“I’ll help you.”

“I’m getting good at this.”

“Remember the branches.”

“I’ll get the tape.”

“I’ll go look for stuff we can use.”

“We can cut it.”

“Hey, remember we are supposed to work as a team.”

After the time was up, students gave a tour of their shared habitat and explained how they incorporated all of the elements of the design challenge (see Appendices O and P for sample pictures of the working stage and final products).

The final components of this engineering process were an individual post assessment of the engineering design process and the ability to articulate what an engineer does (see Appendices J and K). 64% of students could accurately label all parts of the engineering design cycle with another additional 9% simply reversing two steps. This means that 73% of my students were able to explain the engineering design process adequately. 91% of students were able to correctly describe at least three things about an engineer and what they do. This included my student with limited English who at the beginning of the project could not even contribute one idea on what an engineer uses or does and my student who struggles significantly in all academic areas.

Action Plan

The purpose of this action research project was to try to determine if applying developmentally appropriate engineering design challenges would help my first grade students become more persistent, creative and independent problem-solvers. But there was also an underlining question: how could I use

my STEM training to help my students and school be more authentically engaged in STEM learning?

Through the course of this project, I saw my students' confidence blossom and their creativity soar. For my English language learners, I saw growth in their speaking skills. For some students who struggled with the traditional reading, writing, and math curriculum, engineering seemed to be something they were skilled in, and thus, it helped improve their attitudes towards school. The excitement level and engagement in school dramatically increased. While my grade book hinted at improvements in persistence, I found that other factors could have impacted that data, making it less reliable. Persistence is a very hard trait to measure.

I personally felt revitalized, if a bit stressed by squeezing the additional engineering activities and art projects for another master's course into our crowded schedule. I would like to advocate for larger blocks of time devoted exclusively to engineering challenges in the future. One possible way to accomplish this would be to institute a dedicated, school-wide half day set aside for a monthly engineering challenge. This would be similar to our monthly DEAR (Drop Everything And Read) day. To accomplish this, teachers would need to carefully assess the existing curricula and standards to see what lessons could be taught with an engineering component in order to create more of an interdisciplinary approach to engineering.

In 2011, Mann, Mann, Strutz, Duncan, and Yoon Yoon wrote an excellent article on integrating engineering into the K-6 curriculum in order to develop

engineering skills in students. They addressed barriers that prohibit many elementary teachers from implementing engineering challenges in the classroom. Mann, et al., reiterate what many others have expressed, that engineering should not be an additional curriculum added to a crowded schedule, but rather an integrated approach to units already being taught (2011). As teachers discuss what they do in their classrooms, they spark others' interests and gain ideas from their peers. This certainly happened in my grade level while I was conducting this action research project. The more I discussed my project and solicited ideas from my teammates, the more receptive they became to attempting additional engineering challenges.

One of the other first grade teachers added an engineering challenge to a healthy bodies unit. Students were asked to create a helmet to protect a water balloon with a face drawn on it from bursting when it was attached to a skateboard and purposefully crashed into the side of the building. Students were successful if their water balloon did not pop. This engineering challenge was enjoyed by her students and would be something I would like to incorporate in the coming years.

Another teacher added an engineering challenge to our new economics unit on wants and needs. Here groups of students worked cooperatively to "manufacture" a needed household item, such as a bed or refrigerator, during a limited time period. They were challenged to make as many as possible. At the end of the challenge, students' bartered their goods for other things they needed. Again, this challenge was something students could easily relate to and were

successful. This is a challenge I would be willing to add to my curriculum next year.

For this action research project, I located many new engineering themed books that appeal to young students. The books that I was able to read to my students were listed in Appendix D. However, there were other books (see Appendix Q) that I discovered, but was unable to read to my students because of time constraints. In future years, I would like to read the other books throughout the year to complement other engineering projects.

While doing research, I found another teacher who sends monthly engineering challenges home for students to do with their families. It works similarly to a monthly home reading calendar. Students and their families are asked to try to create something unique with simple, inexpensive items like a brown paper bag, rubber bands, or a straw. At the end of the month, students could share their creations with their class and then invite families in for “sharing day.” In addition, I wondered if some of the more unique projects could be displayed at our yearly STEM Expo. I think this may be a wonderful way to engage families and build a stronger community. In addition, I feel like it would help build a common vocabulary for students and their families around engineering. This could become an interesting additional research project next year.

Because I added several trial engineering activities to our units of study, I was curious as to how students perceived the benefits of the additional engineering challenges, as well as which challenges they enjoyed and which

ones they struggled to complete. Luckily for me, 17 of the 22 action research participants are currently in my summer school class. As such, I asked these students to complete an additional survey to help inform instruction for the coming years (see Appendix R). Most of the participants who answered the survey felt the engineering projects helped them become more creative and gain problem-solving skills.

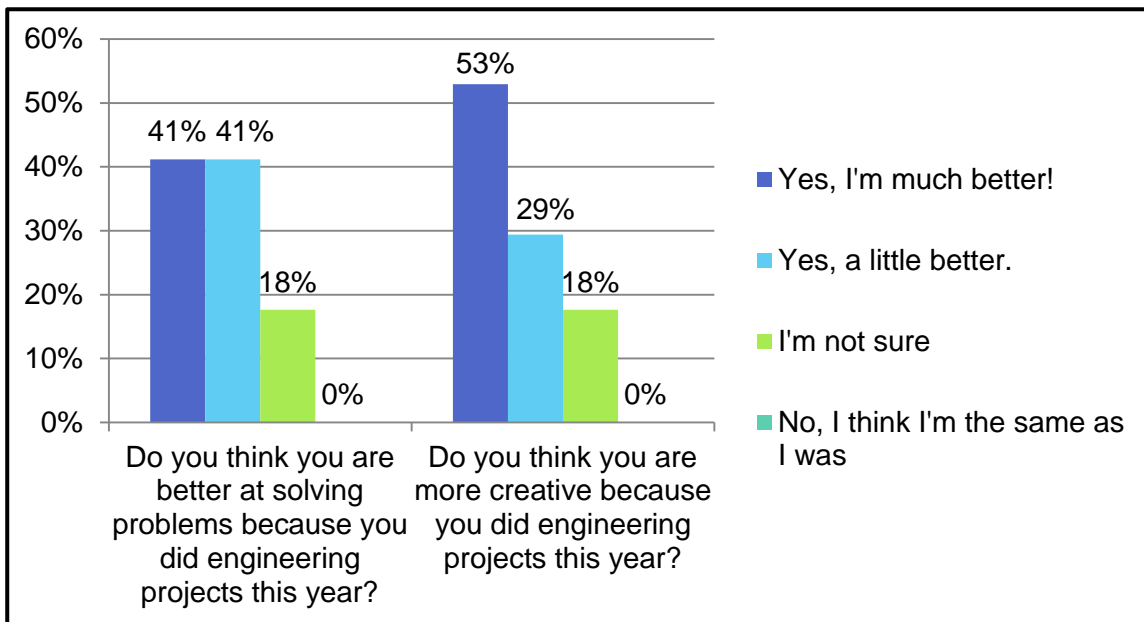


Figure 11: Survey to Inform Future Instruction Results. This figure illustrates the students impressions of their growth based on this study.

As I reflected on the rock and animal habitat projects, I truly felt that students gained a better understanding of what a habitat was because of this project. They were actively engaged throughout the process. As we created more engineering projects, I noticed that students were more supportive and helpful with each other. This was wonderful to see.

If I were to adopt the animal habitat project into our science unit on studying animals, I would recommend that we use sets of plastic animals that are

commonly found in craft stores rather than stuffed animals. This would eliminate any potential socio-economic or cultural differences related to owning stuffed animals. In addition, I felt that many students were so attached to their stuffed animals, that they could not see them as wild animals. They wanted to create imaginative and fun places for their friends to keep them happy. Having an animal that is plastic and belongs to the school may take away some of the confusion between “let’s pretend” and reality. In addition, the animals would be uniformly sized and smaller, making it easier to create a habitat where all the animals fit. Grouping students would be easier as the teacher would have more control of the available choices.

In the additional information instruction survey, I asked students if they enjoyed creating the rock and animal habitats. Their responses were extremely positive. Their satisfaction with the group projects was lower. I believe that this is because students at this age are just developing the skills needed to work cooperatively in groups

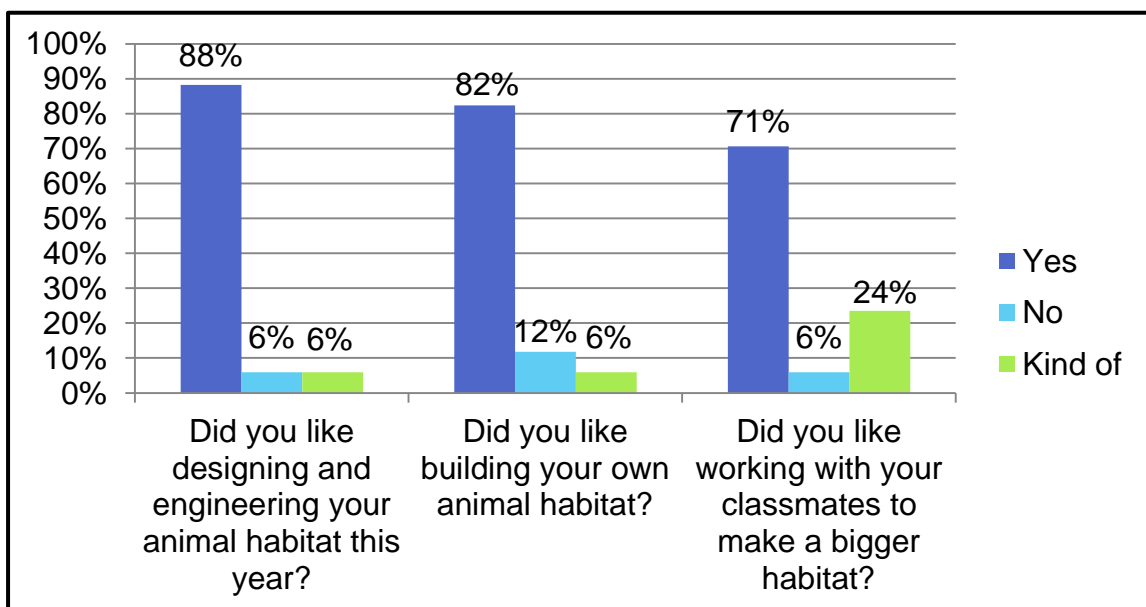


Figure 12: Survey to Inform Future Instruction Results. This figure summarizes students' interest in the various engineering challenges during this study.

But when I asked students which one engineering challenge they liked best this year, the results were somewhat surprising. I had anticipated that it would be the rock or animal habitats. However, the existing flashlight project was the most popular.

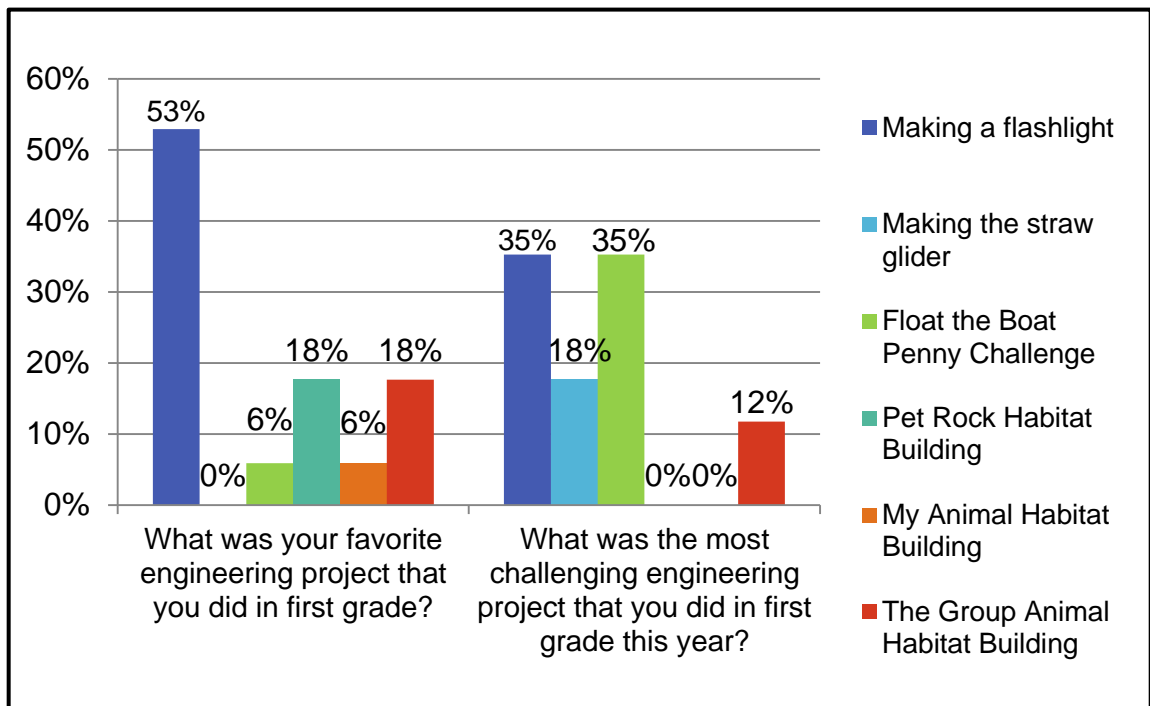


Figure 13: Survey to Inform Instruction Results. This figure illustrates students' favorite, as well as, their most challenging design project during this study.

While I can see the appeal of making a project that they can repeatedly use, it certainly was one that was difficult for first grade students to accomplish. This flashlight project is an excellent example of technology, but not a real engineering design challenge. It is not an engineering challenge because it has a precise order resulting in a 100% success rate, thanks to numerous adult volunteers who assist that day. In addition, first grade students' fine motor skills are not developed enough to allow them to twist wires around small paper clips

and secure them with electrical tape, making it inappropriate developmentally. This project should be critically evaluated in the coming years.

In the end, through the academic research I did for this project and through the results of my classroom project, I firmly believe that engineering has a valid and necessary place in all elementary grades. These challenges do not have to be an additional subject or curriculum item, but rather projects can be created to enhance units already being taught. These engineering design challenges do not need fancy equipment or special training. All that is needed are informed teachers with a desire to help students feel positive about themselves, develop language skills, and help students be more creative. I look forward to working with my teammates and school to expand engineering opportunities in the coming school year.

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Appendix A

Reading Level Correlation Chart

Grade Level	Reading Recovery	Fountas-Pinnell Guided Reading	DRA	Basal Equivilant	Lexile Levels	
Kindergarten	A, B	A	A	Readiness		
	1		1			
	2	B	2	PrePrimer 1		
	3	C	3			
4	4		PrePrimer 2			
5	D	6				
6						
Grade 1	7	E	8	PrePrimer 3		
	8					
	9	F	10	Primer		
	10					
	11					
	12	G	12			
	13					
	14	H	14	Grade 1	200-299	
	15	I	16			
	16					
	Grade 2	18	J, K	20	Grade 2	300-399
		20	L, M	28		400-499
Grade 3	22	N	30	Grade 3	500-599	
			34			
	24	O, P	38		600-699	
Grade 4	26	Q, R, S	40	Grade 4	700-799	
Grade 5	28	T, U, V	44	Grade 5	800-899	
Grade 6	30	W, X, Y		Grade 6	900-999	
Grade 7	32	Z		Grade 7	1000-1100	
Grade 8	34	Z		Grade 8		

Appendix B First Grade Engineering Form

This survey was administered at the beginning and end of the action research project. To visit this form live, go to:
<https://docs.google.com/forms/d/1grjRwk62rJxRMuy9tRsEpeGI-GnxwFI-4gwxhGNCSpY/viewform>



First Grade Engineering

You will do this activity twice. Once before we start our engineering unit and again when we have finished our unit. I want to know what you think and feel. If you think the sentence is correct, mark "Yes." If you think the sentence is wrong, mark "No." Other than your name, there is no "right" or "wrong" answers for everyone.

*** Required**

What is your name? *

I like sharing my ideas.

Yes
 Sometimes
 No

I am a creative person.

Yes
 No
 I don't know

I like to think of new ways to do things.

Always
 Sometimes
 Never - it is easier to do what others are doing

I like solving problems.

Yes
 Sometimes
 No

When I am don't know what to do or have a problem, I

Get frustrated
 Give up
 Try to figure it out by myself
 Get excited because it's a challenge
 Ask the teacher
 Ask a friend
 Do nothing

At school I am able to be persistent (keep working hard) on my schoolwork

All of the time
 Some of the time
 Not much of the time

If something is hard for me to do, I

Give up
 Hate it
 Practice it more
 Work hard at it
 Ask for help
 Know that I will get it someday

Appendix B (continued)

What is an engineer?

- A person who drives a train
- A person who solves a problem
- A person who cleans buildings
- A person who fixes cars
- A person with a different job than above
- I don't know

What should you do first when you are doing an engineering project? *

- Get the materials
- Make a plan
- Make a drawing
- Ask a question
- Try to build something

It is ok if you create or build something that doesn't work. *

- Yes
- No
- Maybe

After you finish an engineering challenge, you should *

(You can check more than one box)

- Tell others what worked
- Explain how your project works
- Tell others what didn't work (failed)
- Try it again to make sure it works
- Make it better
- Take it apart and put stuff away
- Ask more questions
- Feel proud of yourself

When I work on engineering projects, it helps me

(You may check more than one response)

- think creatively
- learn that failing is ok
- keep working on things that are difficult
- try new things
- talk to others about my work
- share materials (things) with others
- share ideas with others
- have fun
- solve problems

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100%: You made it.

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




































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Appendix C
Student Attitude Survey

Name: _____ Date: _____

I think that . . .

	I am	 Awesome	 Just fine	 So-so	 Boring	 Not great
	School is	 Awesome	 Just fine	 So-so	 Boring	 Not great
	Reading is	 Awesome	 Just fine	 So-so	 Boring	 Not great
	Math is	 Awesome	 Just fine	 So-so	 Boring	 Not great
	Writing is	 Awesome	 Just fine	 So-so	 Boring	 Not great
	Science is	 Awesome	 Just fine	 So-so	 Boring	 Not great
	Social Studies is	 Awesome	 Just fine	 So-so	 Boring	 Not great
	Engineering is	 Awesome	 Just fine	 So-so	 Boring	 Not great
	Art is	 Awesome	 Just fine	 So-so	 Boring	 Not great
	Computer is	 Awesome	 Just fine	 So-so	 Boring	 Not great
	Music is	 Awesome	 Just fine	 So-so	 Boring	 Not great
	Phy Ed is	 Awesome	 Just fine	 So-so	 Boring	 Not great

Appendix D

**Recommended Trade Books to Develop
Engineering Skills and Traits of K-2 Students**

- Beaty, A. (2013). *Rosie Revere Engineer*. New York: Abrams Books for Young Readers.
- Belloni, G. (2013). *Anything is Possible*. Berkeley: Owlkids Books, Inc.
- Berry, L. (2013). *What Floats in a Moat?* New York: Abrams Books for Young Readers.
- Breen, S. (2008). *Violet the Pilot*. New York: Dial Books for Young Readers.
- Dodds, D.A. (1996). *The Shape of Things*. St. Louis: Turtleback Books.
- Hunt, E.M. (2010). *Engineering Elephants*. Bloomington: AuthorHouse.
- Mason, A. (2006). *Build It! Structures, Systems and You*. Tonawanda: Kids Can Press.
- Miller, R. (2014). *Engineering in our Everyday Lives*. New York: Crabtree Publishing.
- Miller, R. (2014). *Engineers Solve Problems*. New York: Crabtree Publishing.
- Miller, R. (2014). *How Engineers Find Solutions*. New York: Crabtree Publishing.
- Monroe, C. (2008). *Monkey with a Tool Belt*. Minneapolis: Carolrhoda Books.
- Novak, P.O. (2010), *Engineering the ABC's*. Northville: Nelson Publishing & Marketing.
- Portis, A. (2006). *Not a Box*. New York: HarperCollins.
- Portis, A. (2007). *Not a Stick*. New York: HarperCollins.
- Salas, L.P. (2012). *A Leaf Can Be . . .* Minneapolis: Millbrook Press as part of Lerner Publishing Group.
- Van Dusen, C. (2007). *If I Built a Car*. New York : Dutton Children's Books.
- Van Dusen, C. (2012). *If I Built a House*. New York : Dial Books for Young Readers.

Appendix E
Engineering Creativity Extension to Trade Books

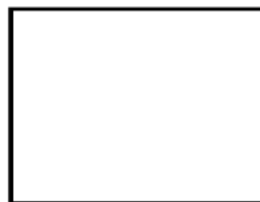
It's not a stick!



It's a _____.

By Engineer _____

It's not a box!

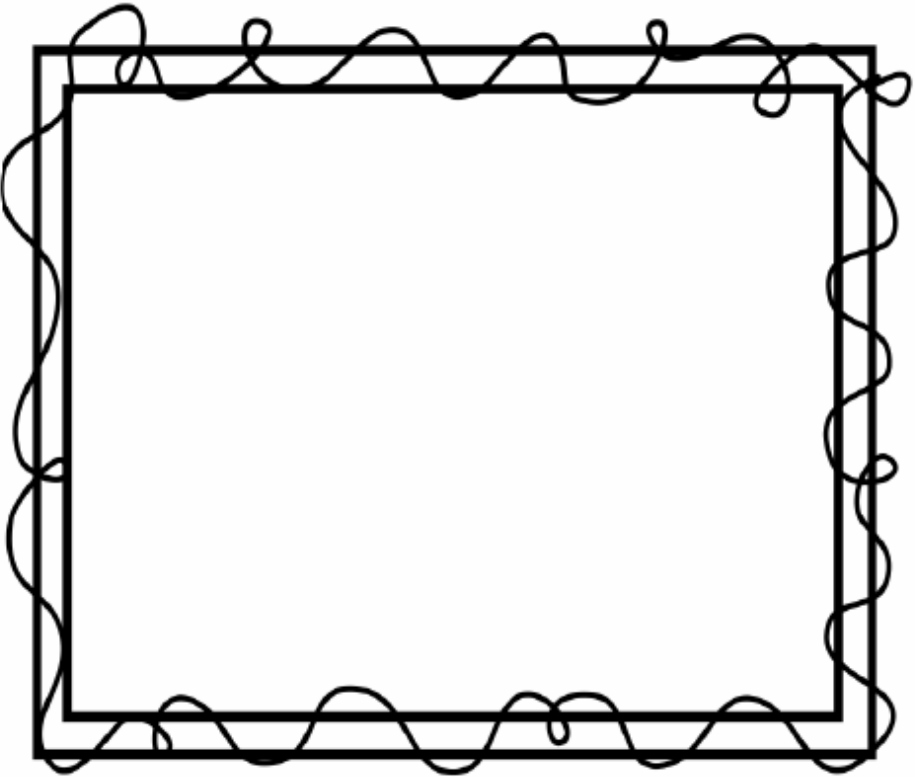


It's a _____.

By Engineer _____

Appendix F
Engineering Creativity Extension to Trade Books

A _____ is just a _____
Until you add _____




Then it's a _____
By _____

Appendix G
Student Engineering Design

Name: _____ Date: _____

I can Engineer!

Problem: _____

➔ Think . . . Plan 

Here's what I created first:

I learned:

I used: _____

My improved design looks like:

My design had:


- _____
- _____
- _____

It worked better.
 It didn't work better.

Appendix H Reflection Journal

Daily Reflection	
Date: _____	
Engineering activity:	
What went well:	What didn't work:
Notes on student behaviors during the engineering activity:	
Student comments during engineering the activity:	
Notes on students behaviors and comments during other parts of the day:	
Co-teacher's comments/observations:	
Plans for tomorrow:	

Appendix I
Sample Page from my Grade book

		Student ID								Assignment name
		1 = Female, 2 = Male								
										Date
	A	1								
	B	1								
	C	2								
	D	1								
	E	2								
	F	1								
	G	2								
	H	2								
	I	2								
	J	2								
	K	2								
	L	1								
	M	1								
	N	1								
	O	2								
	P	1								
	Q	1								
	R	1								
	S	2								
	T	2								
	U	2								

Key to Normal Grading Scale

😊 = 4 (Looks great! Nice **persevering and problem solved!**)

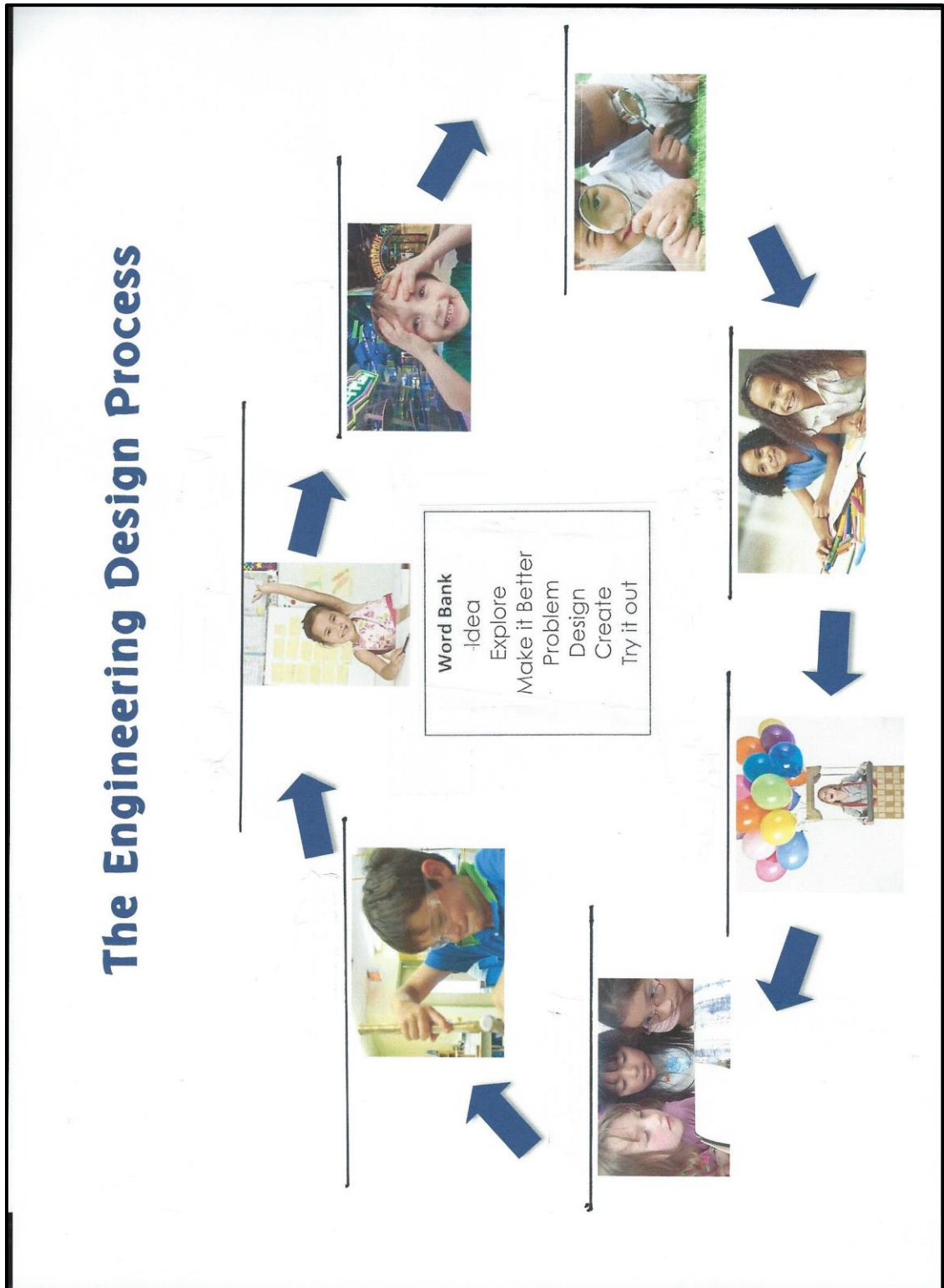
✓ = 3 (Mostly right. You **persevered and problem solved!**)

😬 = 2 (Lots of mistakes or didn't read directions. You forgot to use your **problem solving skills.**)

😞 = 1 (Sloppy, mostly incomplete, not acceptable) You **lacked perseverance and problem solving skills.**)

ND = 0 (Work was never done. **No** evidence of **perseverance, or problem solving skills.**)

Appendix J Engineering Design Process Quiz

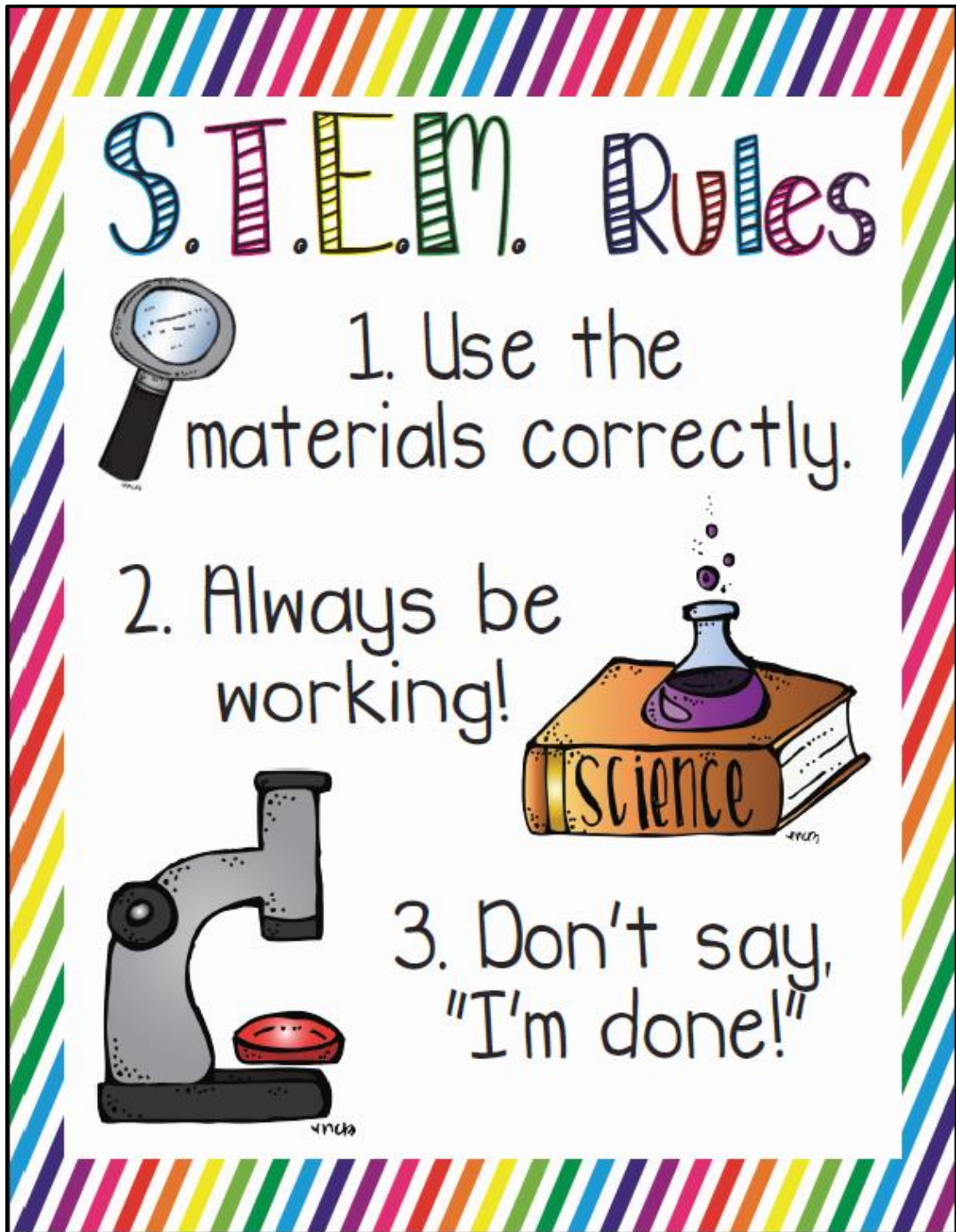


Appendix K
Engineering Tree Map

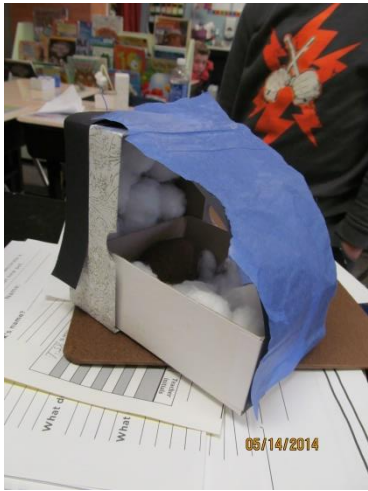
Name: _____

Engineers

AreCanUse

Appendix L
STEM Rules

Appendix M
Rock Habitat Photos



Under a waterfall



ELL student's in
the forest.



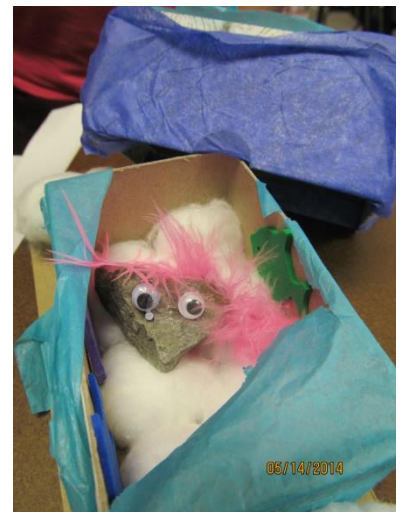
In a swamp.



A snow cloud
hangs above the
habitat.



Example of student's
work with no explanation
what the habitat was.



Under the sea.

Appendix N
Sample Individual Animal Habitats



Appendix O
Samples of Cooperative Team Work in Group Animal Habitat Challenge



Appendix P
Sample Cooperative Group Habitats



Appendix Q
Additional Recommended Trade Books to Develop Engineering Skills and Traits
for K-2 Students

Arnold, T. (2014). *Fix this Mess!* New York: Holiday House, Inc.

Fleming, C. (2013). *Papa's Mechanical Fish*. New York: Farrar Straus Giroux Books for Young Readers.

Gall, C. (2013). *Awesome Dawson*. New York: Little, Brown and Company.

Heder, T. (2013). *Fraidyzoo*. New York: Abrams Books for Young Readers.

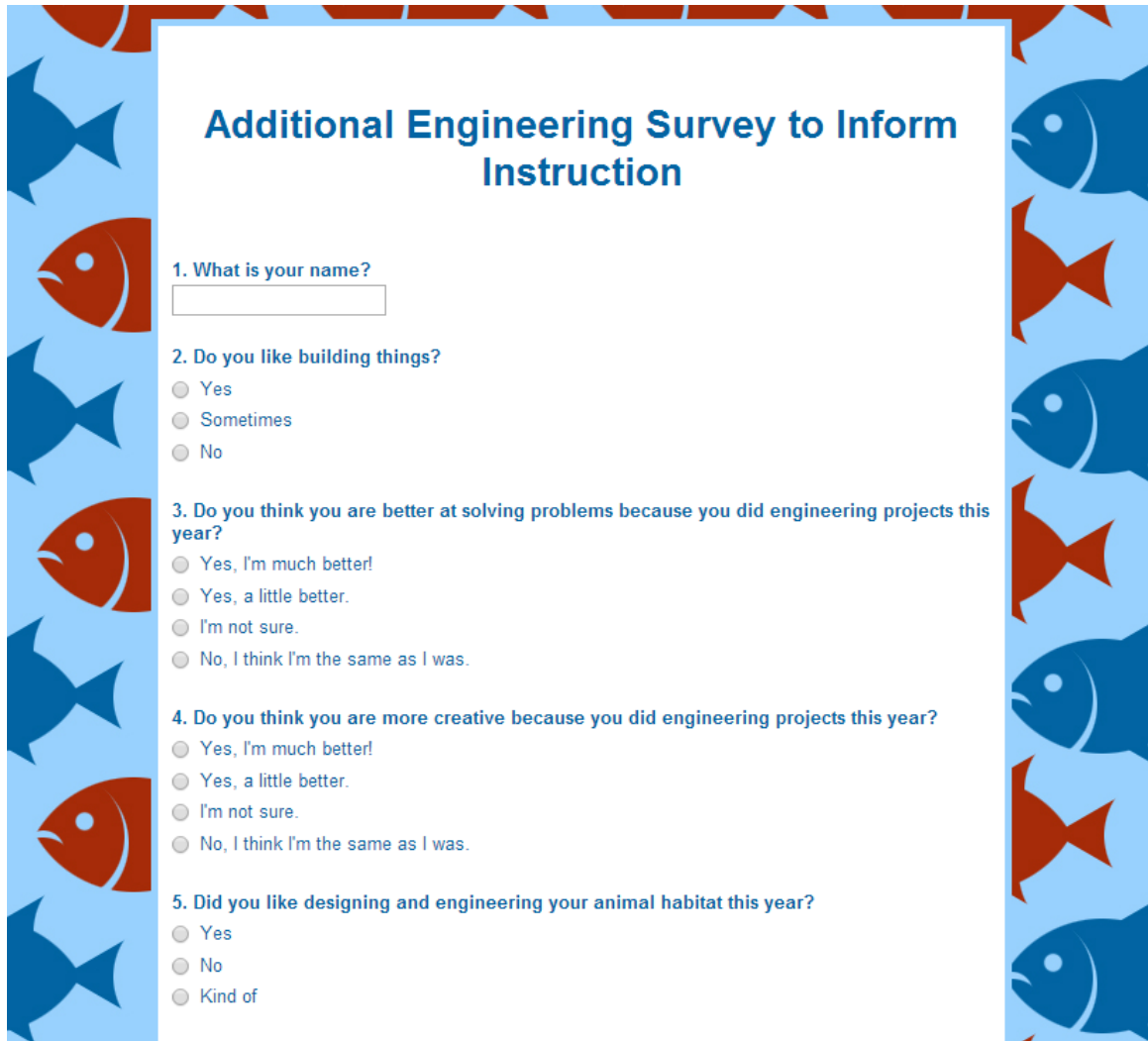
Pett, M. & Rubinstein, G. (2011). *The Girl Who Never Made Mistakes*. Naperville: Sourcebooks, Jabberwocky.

Rivera, A. & R. (2009). *Rocks, Jeans, and Busy Machines*. San Antonio: Rivera Engineering.

Saltzberg, B. (2010). *Beautiful Mistakes*. New York: Workman Publishing Company, Inc.

Zuppari, S. (2013). *The Nowhere Box*. Sommerville: Candlewick Press.

Appendix R
Additional Survey to Inform Instruction for Coming Years



Additional Engineering Survey to Inform Instruction

1. What is your name?

2. Do you like building things?
 Yes
 Sometimes
 No

3. Do you think you are better at solving problems because you did engineering projects this year?
 Yes, I'm much better!
 Yes, a little better.
 I'm not sure.
 No, I think I'm the same as I was.

4. Do you think you are more creative because you did engineering projects this year?
 Yes, I'm much better!
 Yes, a little better.
 I'm not sure.
 No, I think I'm the same as I was.

5. Did you like designing and engineering your animal habitat this year?
 Yes
 No
 Kind of

Appendix R (continued)

6. Did you like building your own animal habitat?

- Yes
- No
- Kind of

7. Did you like working with your classmates to make a bigger habitat?

- Yes
- No
- Kind of

8. Do you like engineering more now than you did in Kindergarten?

- Yes, I like it more!
- No, it's about the same
- I don't really enjoy engineering

9. What was your favorite engineering project that you did in first grade?
Please choose just one.

- Making a flashlight
- Making the straw glider
- Float the Boat Penny Challenge
- Pet Rock Habitat Building
- My Animal Habitat Building
- The Group Animal Habitat Building

10. Which was the most challenging engineering project that you did in first grade?
Please choose just one.

- Making a flashlight
- Making the straw glider
- Float the Boat Penny Challenge
- Pet Rock Habitat Building
- My Animal Habitat Building
- The Group Animal Habitat Building

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