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ELEMENTARY PRESERVICE TEACHERS SELF-EFFICACY AND CONFIDENCE TEACHING ENGINEERING

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ELEMENTARY PRESERVICE TEACHERS SELF-EFFICACY AND CONFIDENCE TEACHING ENGINEERING

THESIS

A thesis submitted in partial fulfillment of the
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By

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ABSTRACT OF THESIS

ELEMENTARY PRESERVICE TEACHERS SELF-EFFICACY AND CONFIDENCE TEACHING ENGINEERING

Engineering has become a popular topic within science standards in recent years. However, many teachers do not have experience teaching or doing engineering. With the possibility of engineering becoming a major part of the science curriculum, it is important that teachers are prepared and well equipped to teach and instruct engineering activities, lessons, and support. This quantitative study studied elementary preservice teachers' self-efficacy and confidence with teaching engineering in the classroom after experiencing and teaching engineering activities. Overall, the implementation of the engineering activities had both positive and negative impacts on preservice teachers' perceptions of themselves and teaching engineering in the classroom.

KEYWORDS: self-efficacy, engineering, elementary, preservice teachers

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TABLE OF CONTENTS

LIST OF TABLES

List of Figures

Introduction

Background and Rationale

Science. Technology. Engineering. Mathematics. Separately, they hold power. When they are combined as one entity, they can work together to help solve complex problems or provide multiple solutions to real world challenges. Science, Technology, Engineering, and Mathematics, or STEM, can be difficult to define beyond the acronym. Often, STEM is used to talk about future jobs that students can obtain. In this context, STEM is used collectively to refer to jobs that are considered "STEM jobs". Other times, STEM refers to what is being taught and/or learned within a school system. In this context, STEM is a mathematics or science subject taught in school. Sometimes schools offer an engineering course, but not often. While STEM may be a household acronym, it has been most often studied in the context of workforce and school systems (e.g., Daily & Eugene, 2013; Hammock & Ivey, 2017).

STEM is important. STEM is not just standing in front of the classroom and talking to students. STEM is more hands-on and involved. STEM experiences can happen either inside or outside of a classroom but are focused on what students observe and take part in related to science, technology, engineering, and/or mathematics. STEM experiences are frequently equated to what one may see in a science or math classroom (Kelley & Knowles, 2016)—science experiments, investigative lessons, math projects, reading text in science or math— these lessons and activities that are designed and executed by the classroom instructor and are witnessed within the walls of classroom. One factor affecting STEM exposure at the elementary (K-5) grade level is the prioritization of teaching reading and mathematics to students over other subjects such as social studies and science (Plans, 2015). Further, engineering is required in the Next Generation Science Standards (NGSS Lead States, 2013). While we are unlikely to change the amount of time an elementary student gets to a particular subject, we can find ways to creatively increase exposure and also advocate for why time with the subject is important. For example, science and engineering allow the students to take real life situations and interact with them, usually through a hands-on investigation.

Engineering also allows for students to engage critical thinking and problem-solving skills. Studies have also shown that students remember science concepts better through the incorporation of engineering (Porter et al., 2019). However, many teachers avoid teaching engineering to their students due to their own lack of knowledge and experience with engineering (National Academies of Science, Engineering, and Medicine, 2020). Moreover, engineering is most often taught during science in K12 classrooms (National Academy of Engineering and National Research Council, 2009). However, science is a subject that is put on a time constraint in many schools and school districts. Because of this time constraint, teachers often partner science with literature. Nevertheless, engineering is part of the science standards (NGSS Lead States, 2013) and it is critical that teachers have the knowledge and skills needed to effectively teach elementary students engineering.

This study sought to the impact of incorporating engineering activities into an elementary preservice teachers' science methods class on their confidence, attitudes and self-efficacy. Specifically, the research question addressed is: How does practicing and implementing engineering activities impact elementary preservice teachers' confidence, attitudes, and self-efficacy toward teaching engineering in the elementary classroom?

Literature Review

STEM integration can provide students with one of the best opportunities to experience learning in real-world situations, rather than learning STEM subjects (Moore et al., 2014). STEM is more than the careers they create. For example, engineering is a natural integrator (Moore et al., 2014). Engineering is often viewed as a vehicle for students to either learn science or apply scientific knowledge and principles to real world design problems (Lie et al., 2021). Students tend to be more engaged in a lesson or activity when they can relate to it. Engineering allows students, teachers, and real-world experiences to comes together to build on things that happen in the real-world. Engineering establishes vital skills such as problem solving, critical thinking, creative design, and teamwork (Porter et al., 2019).

The Next Generation Science Standards

The Next Generation Science Standards (NGSS) helps with the integration of engineering into science with the integration of engineering standards. The NGSS has each standard broken into groups: Science and Engineering Practices (SEP), Disciplinary Core Ideas (DCI), and Crosscutting Concepts (CCC) (NGSS Lead States, 2013). The Science and Engineering Practices explain and extend the science practices within the standard (NGSS). They are the *how* of the standards. The Disciplinary Core Ideas (DCI) are the key ideas in science that have broad importance within or across multiple science or engineering disciplines (NGSS Lead States, 2013). Finally, the Crosscutting Concepts (CCC) helps students explore the connections across all four science domains: Physical Science, Life Science, Earth and Space Science, and Engineering Design (NGSS Lead States, 2013). The NGSS is building a bridge between teachers and engineering by making connections with the science standards they are likely familiar. Within each standard, the NGSS has a Science and Engineering Practices block. The NGSS describes the Science and Engineering Practices as:

> Science and Engineering Practices describe what scientists do to investigate the natural world and what engineers do to design and build systems. The practices better explain and extend what is meant by "inquiry" in science and the range of cognitive, social, and physical practices that it requires. Students engage in practices to build, deepen, and apply their knowledge of core ideas and crosscutting concepts. (para 1)

Each grade level has an engineering component to a standard. Although the NGSS lays out the expectations for engineering and other science standards, it does not attend to preparation needed to teach the standards. The understanding of engineering is essential to comprehending issues about design and the design process and how it is a benefit and not a hinderance to teaching. However, the NGSS including engineering practices and standards should result in an increase of engineering related professional development opportunities for elementary teachers (Hammock & Ivey, 2017, p. 54).

Engineering

What is an engineer? The answer to this question may vary based on a person's experience and their prior knowledge. Some students view engineers as makers/fixers/workers and designers/inventors/creators of products (Driessen et al., 2018). Teachers defined engineering as problem solving (Driessen et al., 2018). Engineering is any engagement in a systematic practice of design to achieve solutions to human problems (Aranda et al., 2020). This systematic practice is called the engineering design process.

The Engineering Design Process is an iterative process used by engineers to engage in systematic problem solving (Driessen et al., 2018). Mangold and Robinson (2013) describe the Engineering Design Process as a decision-making process, often iterative, in which basic science, mathematics, and engineering concepts are applied to develop optimal solutions to meet an established objective. The engineering design process is defining the problem, research, or explore, the problem, brainstorm, analyze, design, build, test, and improve (Science Buddies). The engineering design process is something that would be easy to apply within the classroom. This process gives the students the opportunity to think freely and critically to meet the requirements of the project they are given. It allows students to think of the possible solutions to a problem or make changes to improve an idea. Defining the problem looks at the who, what, when, and where of the presented problem. The students will be given a prompt from the teacher, and they will take that prompt and lay out what the problem is. Once they have noted the problem within the prompt, they will research the problem tells the students and teacher(s) where and how they can find more information about the problem they were given. The real creativity begins with the students brainstorm possible solutions to their problem. The teacher can give the students a designated number of solutions to present, or they can give them a time limit, 15-20 minutes would be ideal, to allow them to come up with as many solutions as they would like.

Analyze and evaluate solutions gives the groups time to prioritize what is being asked of them within the given problem. This could range from a specific price range or a weight requirement that needs to be met. After things have been prioritized, the groups will choose the best solution through further analyzation and prioritization of the solutions they have already created. The teacher could give a time limit of 10-15 minutes to allow the groups to deduce their list of solutions and choose the optimal one. After the students have selected their best solution, they will create a prototype of the object within the prompt. After testing the prototype, the students can make any revisions needed to better their current design. After revisions, testing is conducted again and the process continues until an optimal solution has been found.

The engineering design process provides an ideal platform for integrating mathematics, science, and technology (Mangold & Robinson, 2013). It is important to consider how the STEM components are interconnected (Moore et al., 2014). The integration of the engineering design process and science should be explicit, meaningful, and diminish students' design misconceptions (Lie et al., 2021). The engineering design process should also be considered as a pathway to introduce engineering to all levels of K-12 students (Mangold & Robinson, 2013).

Students as Engineers

Middle school students tend to engage in social problems pertinent to society, whereas elementary school students enjoy designing tangible items (Porter et al., 2019). Both elementary and middle school students like to investigate and are naturally curious. They often use questions to gain understanding of the lesson or activity at hand. Children are natural engineers and technologists who can pursue a goal that meets constraints defined by others and their own personal interests (Brophy et al., 2008). Early elementary learners appear able to articulate, or demonstrate, in their actions, their plans for constructing products with some level of intention (Brophy et al., 2008). Students that view design process as learning are therefore able to acquire scientific knowledge during their design projects and apply that scientific knowledge to the design (Lie et al., 2021). The engineering design process is a step-by-step process, and each step can be viewed as a learning opportunity. The process allows for students to utilize their critical thinking and even teamwork skills to complete a project or task.

Teachers as Engineers

Like engineers, teachers wear different hats in the classroom – from teaching different courses or subjects to attending to the many tasks and duties associated with being classroom teacher. Some students have the same teacher throughout the school day and others may have more than one teacher. Teachers are the foundation of the classroom. Teachers are responsible for laying the foundation for the problem (Porter et al., 2019). Further, Teachers play a critical role in helping students make meaning of the practices and processes of engineering design (Lie et al., 2021).

It is important there is a clear way for teachers and students to engage in the world of engineering within the classroom. Development of critical thinking, meta-cognition, and adaptive/applicable skills beyond engineering are commonly left for the humanities to teach (Mangold & Robinson, 2013). However, the NGSS make it clear that these processes and skills are essential components of teaching science and engineering. The three dimensions of the Crosscutting Concepts, the Science and Engineering Practices, and the Disciplinyar Core Ideas work together to help students build a better understanding of mathematics and science over time (NGSS Lead States, 2013).

Although the NGSS incorporates engineering into the science standards, many teachers are not familiar with engineering nor teaching engineering. Teachers are likely to spend less time teaching in a content area that they have low efficacy in (Hammock & Ivey, 2017). Many teachers lack the content knowledge and experience to make such an evaluation (Brophy et al., 2008). Teachers must become comfortable and proficient with the engineering process and learn to quickly recognize where learners are in the process (Brophy et al., 2008). Teachers need support beyond the standards to increase their confidence, knowledge, and self-efficacy when it comes to incorporating engineering. Just like students need support throughout their learning career, teachers need support for teaching. Teachers need continuous and explicit support to enhance the quality of scientific discourse (Aranda et al., 2020).

External forces (e.g., school schedule, high-stakes testing, lack of resources) and internal forces (lack of pedagogical knowledge) play a role in teacher implementation of engineering (Capobianco & Rupp, 2014). From lack of resources to minimal support, teachers cannot increase their confidence in incorporating engineering when there is no guidance on where to start. Educators, curriculum designers, and educational researchers have long known the benefits of design, troubleshooting, and reverse engineering activities to engage students in rich learning opportunities (Brophy et al., 2008). Teachers need a blueprint for teaching engineering to their students.

Most teacher preparation programs do not prepare elementary teachers to incorporate engineering practices into their classrooms (Hammock & Ivey, 2017). Without preparing or teaching the teachers in their professional development programs *how* to incorporate engineering into their lessons, there will not be much change in engineering being incorporated into the lessons. Elementary teachers feel unprepared to teach engineering concepts and practices to their students (Hammock & Ivey, 2017)

Even apart from the concepts, elementary school teachers find it difficult to teach engineering when they lack an understanding and education of engineering themselves (Porter et al., 2019). Teachers' perceptions of engineering are affected by their limited understanding of engineering (Hammock & Ivey, 2017). Teachers must use effective teaching approaches to support students in engaging in the discourse practices of design or design reasoning, similar to the science and engineering practices found in the NGSS (Lie et al., 2021).

Teacher Self-Efficacy and Confidence

Self-efficacy is an individual's confidence in their ability to organize actions to solve a problem or complete a task and indicated that efficacy beliefs may be impacted by mastery experiences (Nesmith & Cooper, 2020, p. 253). Engineering self-efficacy may vary due to background knowledge and personal learning experiences related to engineering or design principles (Nesmith & Cooper, 2020, p. 253). Engineering self-efficacy may be positively impacted through mastery experiences that allow a teacher to experience engineering actively and successfully (Nesmith & Cooper, 2020, p. 253). Self-efficacy refers to one's belief in his or her ability to produce a desired outcomes (Hammock & Ivey, 2017, p. 53). Self-efficacy develops from four information sources: performance accomplishments, vicarious experiences, verbal persuasion, and emotional arousal (Hammock & Ivey, 2017, p. 53).

Teacher self-efficacy is a teacher's belief in their ability to influence student learning (Hammock & Ivey, 2017, p. 53). Teaching self-efficacy is dependent upon teachers' content knowledge and pedagogical content knowledge (Hammock & Ivey, 2017, p. 53). Enhanced pedagogical content knowledge could lead to more student success in the classroom which can enhance teacher efficacy (Hammock & Ivey, 2017, p. 53). Very few elementary teachers have coursework in engineering which suggests that they may lack the necessary knowledge to teach engineering, which may result in low engineering teaching self-efficacy (Hammock & Ivey, 2017, p. 53).

"Attitude is the psychological tendency to classify an object in terms of favorable or unfavorable dimensions (e.g. good/bad or pleasant/unpleasant)" (Thibaut, 2017, p. 3). When talking about dimensions, it can refer to the lesson at hand. Does the teacher see the importance of the lesson? The teachers' attitude toward the lesson does affect the outcome and perception of it to students. Engineering embodies STEM integration, making the measure of attitude toward engineering an ideal agent for attitudes toward STEM in general (Nadelson et al., 2013, p. 159). Teacher confidence for STEM is an important predictor of ability to teach STEM-related content (Nadelson et al., 2013, p. 159). Nadelson et al. (2013) also states that the relationship between teacher effectiveness, teacher knowledge, and their confidence provides a rationale for addressing and assessing teacher confidence in STEM development.

Conclusions

The engineering design process does not stop at just stop at projects and engineering. It is a process that can be used at any time. Teachers are the engineers of their classrooms. Although they may have doubts about incorporating and teaching engineering, there is a possibility that teachers becoming the students before the teacher of engineering incorporations could help with their ideals and misconceptions about themselves and engineering practices.

METHODOLOGY

The purpose of this quantitative research study was to study the impact of incorporating engineering activities into an elementary preservice teachers' science methods class on their confidence, attitudes and self-efficacy. Specifically, the research question addressed is: How does practicing and implementing engineering activities impact elementary preservice teachers' confidence, attitudes, and self-efficacy toward teaching engineering in the elementary classroom?

This study took place in one section of an elementary science methods course at a large predominately white university in the Midwest United States. There were 25 students who were invited to participated in the project. Twenty-four of the students consented. All the students identified as female. The elementary preservice teachers will be certified to teach K through sixth grade upon successful completion of their program.

Instrumentation for this study was drawn from the Friday Institute at North Carolina State University's T-STEM Survey. This survey was created to measure changes in teachers' confidence and self-efficacy in STEM subject content and teaching (such as engineering), use of technology in the classroom, 21st century learning skills, leadership attitudes, and STEM career awareness (Friday Institute, 2012). The initial survey sections (each contained 4-11 items) were edited based on reviewing the survey instrument and deciding what data would be needed to help answer the research question. Based on review of the instrument, review of the literature, and consultation with the thesis chair, one section of the survey was dropped. The final survey contained the following sections – Engineering Teaching Efficacy and Beliefs, 21st Century Learning Attitudes, Teacher Leadership Attitudes, and STEM Career Awareness. Items within each section were left the same in order to preserve reliability and validity of the instrument.

While I served as the lead researcher for this project, my role in the course was as a teaching assistant. I help to set up activities for the course instructor and was generally available throughout the class as needed. In planning for this study, I met with the lead course instructor several times to determine the engineering standards and talk through the engineering design process. We identified research-based, hands-on engineering activities that would allow preservice teachers to experience the engineering design process while keeping consumable materials at a minimum. We also wanted to ensure the instruction and activities would be relevant to preservice teachers' placements and would be activities they could easily implement in their future classrooms. While the focus of the activities were on the engineering design process, we also identified a common theme of projectile activites in order to also tie in the science standards of forces and motion. The lead instructor had found that incorporating engineering design activities with other science standards led to a stronger chance of the science and engineering lessons being taught in the elementary classroom.

I worked to create lesson plans and activitiy guides for the elementary preservice teachers. When creating the lessons, I first thought about the preservice teachers being the students during these activities. It is important that teachers take the time to be a student before being the teacher. With the preservice teachers doing the activities first, they can get an idea of how their students act when doing the activity within their classroom. I then thought about the elementary students completing the activities, with the preservice teachers leading the activities. These lessons can be found in Appendix A.

Connection to the NGSS Standards

With the engineering activities being taught and implemented in the preservice teachers' elementary science methods course, it is important to show how these activities relate to the class and the NGSS standards. Further, it's important to ensure the activities use the engineering design process. The engineering design process is a decision-making process in which basic science, math, and engineering concepts are applied to develop optimal solutions to meet an objective (Mangold & Robinson, 2013). The engineering design process is defining the problem, research, or explore, the problem, brainstorm, analyze, design, build, test, and improve (Science Buddies). The engineering design process gives the students the opportunity to think freely and critically to meet the requirements of the project they are given. It allows students to think of the possible solutions to a problem or make changes to improve an idea. Table 3 shows the engineering activities, the learning outcomes, and the engineering components for each. Although the engineering components are the same across the activities, it is important to show the connection of the activities to the science standards as well as the engineering design process.

Table 1: Engineering Activities and the Engineering Components

Engineering Activity	Learning Outcomes	Engineering Components
Blast Off	Using the balloon and four cups, you will make a simple balloon rocket and test how you can achieve the **greatest** launch distance.	
Slingshot Straw Rockets	Design and build small straw rockets and launch from YOUR slingshot. See how far you can launch your rockets!	
Popsicle Stick Catapult	In this activity you will build a catapult using simple items. You will investigate how you can hit a target using your simple catapult.	Engineering Design Process focusing on - Design, build, test, and improve K-2-ETS1-2, K-2-ETS1-3, 3-5-ETS1-2, and 3-5-ETS1-3
Cotton Ball Launcher	How can you send cotton balls flying with a toilet paper roll? How far can you do it? In this activity, you will design and build cotton ball launchers and see how far you can launch the cotton balls!	
Paper Flier	Can you create a flier that travels far? Let's find out!	

Implementation of the Study

This study took place over the course of 8 weeks. Prior to the start of this study, preservice elementary teachers took the modified TSTEM survey via paper and pencil. The survey took about 10 minutes to complete during class.

The next class, the preservice elementary teachers focused on engineering in the elementary school science classroom. Preservice teachers completed a warm-up activity about the engineering design process and its steps. Then, preservice teachers learned about the importance of incorporation engineering into the science classroom. It is important to let the preservice teachers know that incorporating engineering into the classroom is not to encourage their students to become engineers, but rather give them the experience with hands-on activities, critical thinking, as it relates to engineering, and their everyday life. The preservice teachers are the engineers for the day, but when they go to teach the activities with elementary students, they will be the teachers.

The preservice teachers were then divided into five (5) groups and assigned an engineering activity. Short activity descriptions follow. For full lessons, please see Appendix A.

1. *Blast Off*- The preservice teachers created a "rocket-like" item using a balloon, various cups, and tape. The preservice teachers tested out four types of cups that varied in size and material. They investigated which cup and balloon combination creates the furthest launch distance.

2. *Slingshot Straw Rocket*- This activity involved straws, paper, tape, paper clips and rubber bands. The preservice teachers tested how the rubber band and paper affected the distance of the rocket. The rubber band was a key factor in the distance, but the paper triangles size created different types of drag which can slow the object down.

3. *Popsicle Stick Catapult*- Popsicle sticks can be used for more than just popsicles and ice cream. In their group, the preservice teachers used, rubber bands, a spoon, and popsicle sticks to create a catapult that would launch a ping pong ball, a cotton ball, a pom pom, and a bouncing ball. They created a target to see how far each "round" object would go. They not only changed the object launched, but they also changed the location of the spoon on the catapult to see if that made a difference in how the object is launched.

4. *Cotton Ball Launcher*- This activity is a very intricate one. The preservice teachers used cardboard tubes, duct tape, rubber bands, cotton balls, and a pencil to create this launcher. The pencil and the rubber bands were the ignition to the launching. Like the *Slingshot Straw Rocket,* the distance the rubber band is stretched plays a significant role in how far the item is launched. The preservice teachers were also able to change the launched object to see what the differences are in launching and distance launched.

5. *Paper Flier*- This activity uses straws, paper, and tape to create an object like a paper plane. The preservice teachers cut the papers into circles and taped them to each end of the straw. They were to cut six strips to create circles of different sizes. The group investigated whether the size of the circles changed how the paper flier traveled and how far it traveled.

Data were collected based on the distance of the final products when testing them. Many of the groups tested their activities in the hallways so that they could see and measure the distance of their activity. Each activity had trials to see what they would change. This allowed for them to utilize the engineering design process to enhance their final product. After about 30-40 minutes of building and testing, the preservice teachers came back into the classroom to fill out their data sheets. Although they worked in groups, the students submitted their data sheets individually. This allows for the professor and I to see how they think about the activities individually and how they would change it when teaching younger students.

The class did come back together to discuss what they did, what they changed, and how they would teach it to younger students. There were great ideas for distributed parts of an activity to compare results. Each group had one person speak on what they did and what changes they made during the building process to test their activity. They even offered up ideas about what they could change to improve the activity. Teachers tend to use triadic dialogue, which results in minimal student participation in classroom discussions (Aranda et al., 2020). Aranda et al. (2020) states that teachers should encourage students to ask questions and engage in classroom discussion. Allowing the preservice teachers to explain what they did, how they did it, and how they would teach it is important to see how they may want their students to interact during the activities. While it would have been ideal for each group to rotate to each of the other 4 engineering activities, time constraints in the course did not allow for group rotations. Each group only experienced the one activity they were assigned to so they could be fully immersed in the engineering design process for that activity.

The following class, the preservice teachers took the same modified TSTEM survey via paper and pencil.

The following six weeks, the elementary preservice teachers were in the field for their practicum experience. I had no direct interaction with the preservice teachers during this time.

After their six-week practicum experience, the preservice teachers had the opportunity to teach one of the engineering activities to Kindergarten through third graders at a local elementary school in a public urban district in Midwest United States. The purpose of the elementary preservice teachers teaching the engineering activities was to gain confidence in teaching engineering and science and practice facilitating the engineering design process with elementary students. Only four activities that were previously experienced with the preservice teachers were implemented at the school: Slingshot Straw Rocket, Popsicle Stick Catapult, Cotton Ball Launcher, and Paper Flier. The preservice teachers chose not to teach Blast Off because they felt that the elementary students would get bored with it quickly.

The original intent of this experience was for the elementary preservice teachers to teach the same engineering activities they had experienced prior to practicum. However, the lead instructor made a last-minute change and allowed the preservice teachers to choose which activity they wanted to teach. Approximately 6 elementary preservice teachers co-taught their chosen activity together. Time was allotted prior to the beginning of the teaching for the preservice teachers to make any last minute lesson changes, discuss particular classroom management strategies, and ensure equitable co-teaching amongst themselves. The K-3rd grade students rotated through each of the four stations, spending about 30 minutes at each station. Each station was in a room large enough to accommodate the preservice teachers and elementary students and to conduct the necessary trials for the activities. The time was also sufficient for building and revising the object. As the lead researcher, I was assigned to the Slingshot Straw Rocket. The lead instructor and another professor rotated through each of the activities to provide assistance to preservice teachers and K-3 students as needed.

The following class period, the preservice teachers completed the modified TSTEM survey for a third time via paper and pencil.

Data Collection and Analysis

Preservice teachers were given three (3) surveys via paper and pencil: Pre-engineering activities, post-engineering experience, and post engineering teaching experience. These surveys were derived from the Teacher Efficacy and Attitudes Toward STEM (T-STEM) Survey (Friday Institute, 2021). Only the portions that focused on teacher confidence and self-efficacy were used. These sections were picked due to their ability to generate data that would help answer the research question. The other sections of the survey related to inservice teachers and were not appropriate for the population of this study. The survey (Appendix B) asked the preservice teachers to rank their confidence of engineering in the classroom, teaching engineering and the importance of engineering.

The preservice teachers were given a pre-survey, prior to the first day of engineering activities, to get a basis of their confidence and self-efficacy about teaching engineering to students before administering the engineering activities. A second survey was administered after the preservice teachers experienced the engineering activities themselves. The second survey would show if their confidence decreased, remained the same or increased based on the activity they experienced during class. The final survey was administered after the preservice teachers taught the engineering activities in the field to students. Each survey depicts whether the preservice teachers' self-efficacy and confidence increased, decreased, or remained the same. It was predicted that there would be a positive trend and understanding why things may or may not have changed and how it can be improved in future research.

Survey fatigue is a common issue within research. Survey fatigue occurs when the participants become uninterested or tired during the research study. This is important to notice due to a lengthy survey given multiple times and done by hand. The researcher attended to survey fatigue by spreading out the survey opportunities as much as possible. The surveys did not occur on the same days as the engineering activities.

To analyze the data, the survey results were transcribed into Microsoft Excel. The results were separated by Survey 1 (pre), Survey 2 (after engineering activities), and Survey 3 (after teaching engineering activities). There were four question sets, Engineering Teaching Efficacy and Beliefs, 21st Century Learning Attitudes, Teacher Leadership Attitudes, and STEM Career Awareness, that focused on the preservice teachers and their feedback on teaching engineering. The question sets had ranking responses: Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, and Strongly Agree. For numeric ranking, the responses were coded one (1) through five (5), respectively. The responses from each preservice teacher were averaged across each question. Sums for each of the four major sections were calculated for each student and then the average was found across each section. The following bar graphs display the results of each question set from each survey administration. The average of the responses was used to measure the preservice teachers' growth in self-efficacy and confidence. Missing data were removed from the dataset and mean calculations were adjusted to reflect the number of preservice teachers responding.

RESULTS

The purpose of this quantitative research study was to study the impact of incorporating engineering activities into an elementary preservice teachers' science methods class on their confidence, attitudes and self-efficacy. Specifically, the research question addressed is: How does practicing and implementing engineering activities impact elementary preservice teachers' confidence, attitudes, and self-efficacy toward teaching engineering in the elementary classroom?

Engineering Teaching Efficacy and Beliefs

Figure 1 displays the results of the responses across all three survey time points for the Engineering Teaching Efficacy and Beliefs. This group of questions focuses on the preservice teachers' self-efficacy and confidence with teaching engineering. Teacher self-efficacy is a teacher's belief in his or her ability to influence student learning (Hammock & Ivey, 2017, p. 53). Each question dives into the teachers' view of their engineering teaching and their confidence in it. With the survey given in increments, this question set quantifies their growth or decrease over the study. This allows for there to be a comparison of the preservice teachers practicing the activities and teaching the activities. Overall, with the exception of Question 5, there was a significant increase between the first and second survey, however, there was less of an increase between the second and third surveys.

Question 5 of this question set had a different trend compared to the others. Question 5 stated "I wonder if I have the necessary skills to teach engineering." This observation ties directly back to the teachers' confidence and self-efficacy about teaching engineering. This is where their uncertainty of their ability begins. This question alone can show the growth that preservice teachers may experience throughout the study. The overall results of question 5 shows that the preservice teachers initially were unsure of their ability. After performing the activities in class, they were more sure of themselves and their ability. When they taught the students, the results matched with the results from the first survey. Was there an increase in confidence after performing the activities themselves with other preservice teachers? Were these activities ones that they felt they could manage within the classroom? By the third survey, the responses increased. The third survey came after the preservice teachers taught the engineering activities to elementary students. Did the execution of the engineering activities make them question their capabilities of teaching?

Question 7 states "Given the choice, I would invite a colleague to evaluate my engineering teaching." There is a positive trend where the preservice teachers would allow another teacher to evaluate their engineering lesson, but there is no difference from the second survey to the third. There were a few teachers that were consistent in not allowing another teacher to evaluate their engineering teaching. Porter (2019) states that collaboration between teachers allows for efficient and affective teaching. Aranda et al. (2020) explains that teachers need continuous and explicit support to enhance the quality of scientific discourse. It is also mentioned that when teachers have a strong support system of their lessons and teachings, there is a boost of confidence in teaching different materials. What is the difference when it comes to engineering? Every preservice teacher may not have to teach science or engineering, but it is important to understand why a teacher may not want another teacher's feedback on their teaching. The preservice teachers' efficacy and confidence increased across the surveys. Did doing the engineering activities before teaching them help with this confidence? Did the preservice teachers working in groups help with their confidence in teaching the engineering activities?

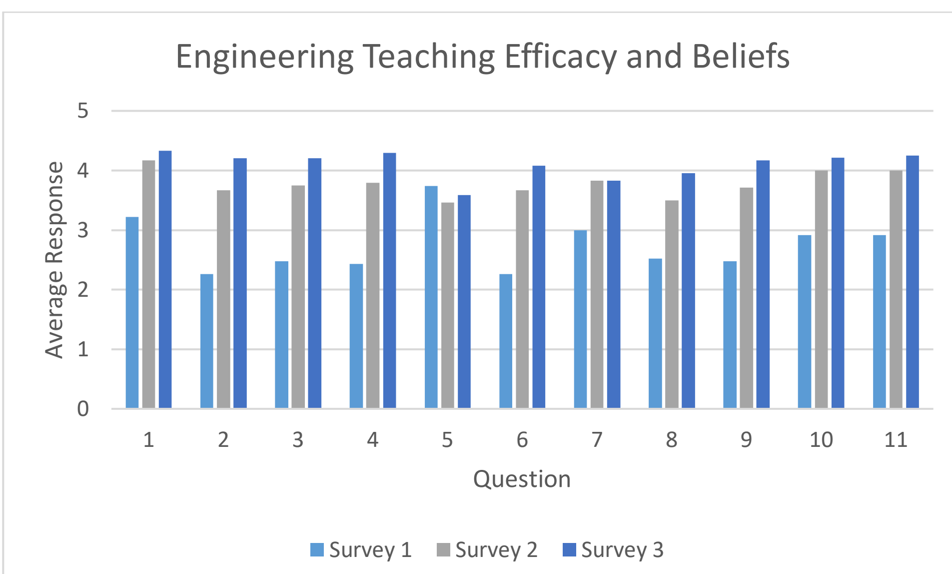


Figure 1: Engineering Teaching Efficacy and Beliefs

21st Century Learning Attitudes

The 21st Century Learning Attitudes questions refer to attitudes and expectations toward learning. How does this tie into the self-efficacy, confidence, and attitude of the preservice teachers? Teachers are expected to teach students in the best and most efficient way possible. Feedback of their teaching is often given through assessments and projects, but the questions in this group focus on teachers' general view of learning and learning opportunities. This is an important aspect of teachers' attitude and self-efficacy because they are thinking about how their teaching is perceived. This also opens their eyes to the diversity that may enter their classroom and how they can approach learning no other from themselves, but from other students as well.

"I think it is important that students have learning opportunities to..." This statement ties into the students understanding of engineering and how they may get that knowledge. Learning does not happen just between teacher and student. It can occur from student to student. Figure 2 shares results. Note the scale is different due to the limited variability between the surveys and wanting to show the small differences between survey timepoints.

The results between survey one and survey two in this groups of questions were close in all but one question, question 10. The statement for number 10 was: "I think it is important that students have learning opportunities to *choose which assignment out of many needs to be done first.*" The survey results had a significant increase from the second to third survey. The preservice teachers were given the lesson plans when they were the "students" and working with the engineering activities to understand the process. They were given time before going into the school to review and talk with their activity groups about a plan for teaching the engineering activities to the K-3 students. The day the activities were administered to the K-3 students, the preservice teachers were not initially given the lesson plans. Even after they received the plans, they did not use them as much. Was this because they were able to depend on one another? Did they feel more confident after creating a teaching plan before the first group of students?

There is a consistent decrease in positive responses from survey 1 to survey 2. Questions 2 and 11 show a consistent decline compared to the others. Question 2 states "I think it is important that students have learning opportunities to encourage others to do their best." After experiencing the engineering activities in class, the preservice teachers seemed to think highly of students encouraging others compared to their responses after teaching the activities to students. Did the preservice teachers feel that encouragement was needed after they did the activities, but saw something different when they administered the lesson to K through third grade students?

Question 11 states "I think it is important that students have learning opportunities to work well with students from different backgrounds." The preservice teachers are aware of students coming from different backgrounds and having different ways of learning. It is highlighted for preservice teachers to be aware of these differences when creating lessons plans. After experiencing the activities among themselves, they felt that it was important for students to have the learning opportunities. When they taught the activities to students, the preservice teachers' responses decreased rather than increased. Did the school environment and activity pairing change their idea about how students learn from other students as well? Did they teach the activities in a way that did not involve the students to work together?

The overall results of the 21st Century Learning Attitudes did not show an increase between survey implementations. Do the preservice teachers need more time with the activities and students to see an increase in confidence and self-efficacy in the students' learning? Why did the survey results decrease after each survey? Did the preservice teachers put themselves in students' shoes when doing these activities?

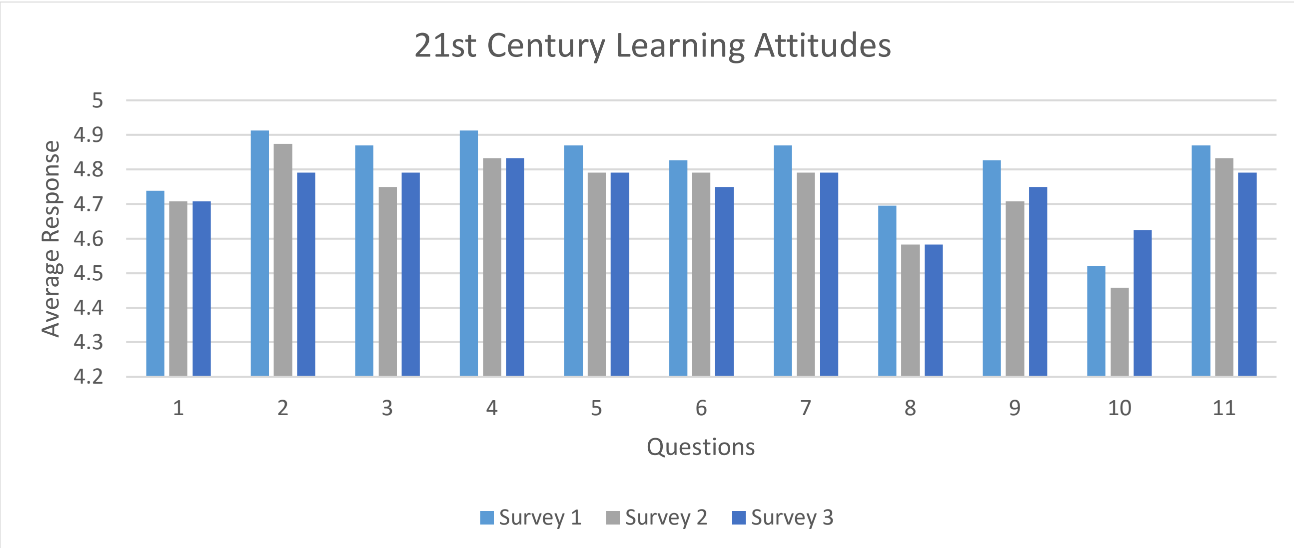


Figure 2: 21st Century Learning Attitudes

Teacher Leadership Attitudes

This group of questions has the teachers focus on teachers' leadership. The preservice teachers think about teachers and their contribution to learning or their idea of learning from their experience. Overall, the data show a decrease in teacher leadership attitudes with the exception of question 3. While the decreases were very small and could be due to survey fatigue, they are interesting to investigate.

Question 1 states "I think it is important that teachers *take responsibility for all students' learning.*" The results for this question are interesting. Surveys 1 and 2 yielded the same results, but there was a slight decrease by the third survey. After teaching the engineering activities to the students, the preservice teachers may not have realized that what they do can drive a student to perform better. The unfamiliarity of the engineering activities may have caused them not to want to take on the responsibility of all students' learning. Teachers are more confident when they know the material they are teaching. If they are unfamiliar, then there will be hesitation. Could the thought of "underperforming" cause them to not want to hold all the responsibility?

Question 3 states "I think it is important that teachers *use a variety of assessment data throughout the year to evaluate progress.*" This question was the only question with an increase in survey responses after teaching the engineering activities to students. The preservice teachers could have looked at these activities as ways to check progression of students learning with engineering.

Another interesting response set is within Question 5: "I think it is important that teachers *establish a safe and orderly environment.*" The responses decreased after each survey. The teacher is expected to maintain their classroom and even learn about classroom management throughout their schooling. What was the difference with this classroom? It could have been that the preservice teachers co-taught the activities together. There could have been a decrease due to the fact that the preservice teachers had just completed their practicum experience and felt their schools and classrooms were already safe and orderly.

Teacher leadership attitudes is important because this is how a teacher views themselves as leaders in the field. These statements shed light on the preservice teachers' ideas of leaders and their confidence within them. Overall, the data show preservice teachers' slightly decrease in their attitude toward teacher leadership with each survey. It is unclear from the data whether this is due to the engineering activities they experienced and facilitated or if it could have been due to their practicum experience during the middle of the study.

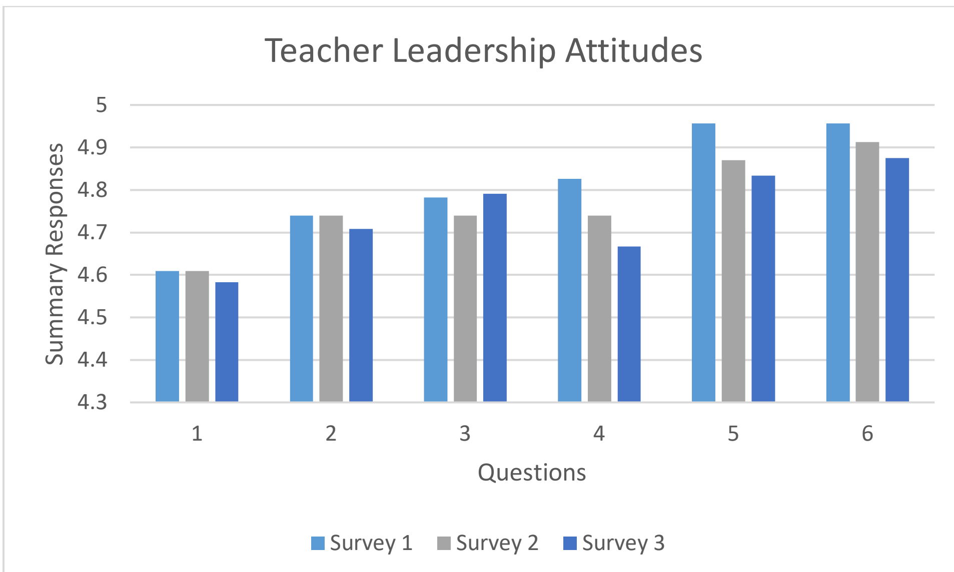


Figure 3: Teacher Leadership Attitudes

STEM Career Awareness

While not directly related to self-efficacy and confidence, STEM career awareness is important for advancing the STEM field, especially engineering. This question set provides evidence of what preservice teachers know about STEM careers and how to access them. Overall, Figure 4 shows a positive trend with each survey administration. The responses show that the preservice teachers are confident in their ability to get students the information they need should they ask for it.

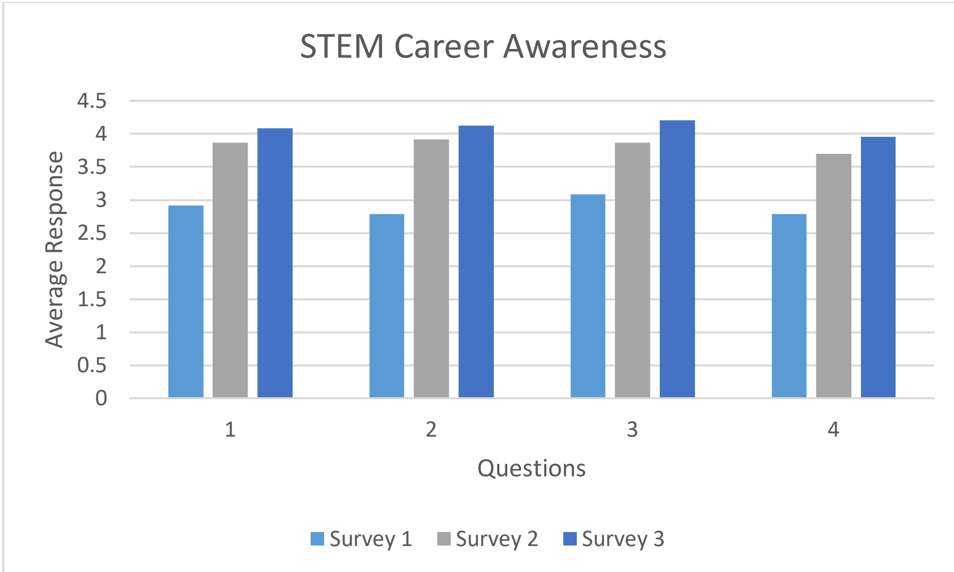


Figure 4: STEM Career Awareness

Survey Summary

Teachers must use effective teaching approaches to support students in engaging in the discourse practices of engineering design process (Lie et al., 2021). Individually, each survey set displayed a slight decrease amongst a majority of questions, but Figure 5 shows that there is an overall increase except for the 21st Century Learning Attitudes. The preservice teachers gained more confidence when they had the chance to be the student before being the teacher when it came to the engineering activities. Engineering design activities can be used in science classrooms, but the attention should be paid to the science pedagogy (Schnittka et al., 2010).

The 21st Century Learning Attitudes and Teaching Leadership Attitudes yielded the closest results between the three surveys. The 21st Century Attitudes decreased in the second survey, and the third survey showed no increase or decrease compared to the second survey. Because this group was focused on the students' learning, it is important to look at the result based on how the preservice teachers viewed themselves when the students are learning. The preservice teachers may not have seen the connection between students' learning and the engineering activities. Teaching Leadership Attitudes shows a slight decrease between survey 1 and 2 then a slight increase from the second and third survey, respectively. The preservice teachers may have lost some confidence when they were the students building and learning the activities but gained it back when they were able to teach the activities to students.

The STEM Career Awareness section showed a positive increase at each survey timepoint. While this study did not explicitly focus on STEM career awareness, increasing career awareness, especially related to engineering, is an important component of integrating engineering into the K12 classroom. It is clear that the preservice teachers' awareness and knowledge of STEM careers increased over time. This could have been due to their own engineering experiences and could have also been attributed to their practicum experiences.

It is important to note that each survey set should not be compared across each other as they each contained a different number of questions.

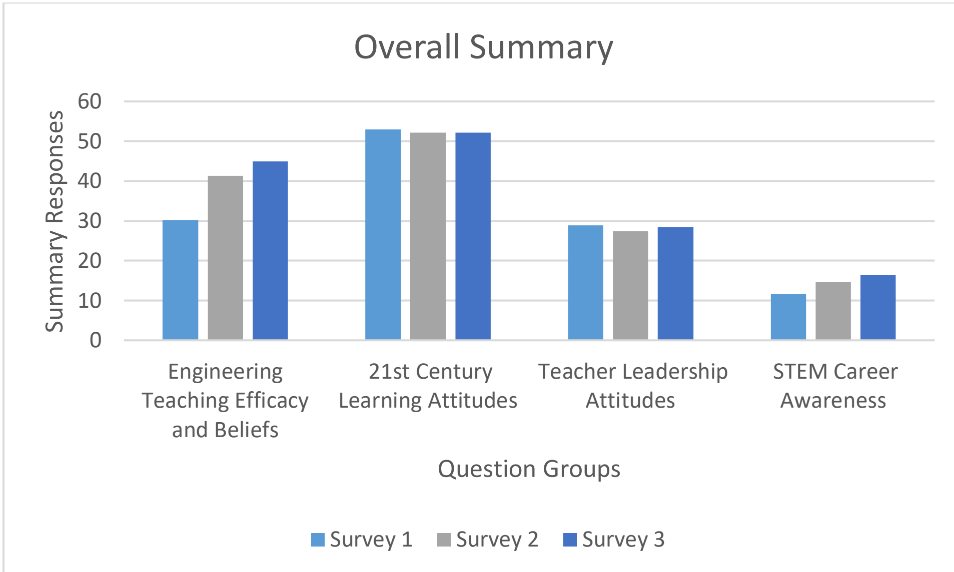


Figure 5: Teacher Efficacy and Beliefs in Teaching STEM

Limitations of the Study

This study took place in one section of a methods course at one university, and so the results are not generalizable and are limited. Further the original plan of having preservice teachers experience each engineering activity was not able to be carried out due to time limitations within the methods course.

The survey data is self-report and it is assumed that the preservice teachers took each survey seriously and gave honest answers. Survey fatigue is a concern in this study as there was approximately 1 week between Survey 1 and Survey 2 administration. Further, Survey 3 was administered after a major field experience (i.e., practicum), which could have influenced preservice teachers' responses.

Finally, the preservice teachers taught the K-3 students the engineering activities after practicum. This may have enhanced their confidence with teaching the students the engineering activities even though they had not taught engineering activities before.

FUTURE RESEARCH

"I wonder if I have the necessary skills to teach engineering." This is a key question that could be asked periodically when preservice teachers are creating an engineering lesson. Teachers need a basis for their engineering knowledge. There should be more investigation into this question with regards to the preservice teachers' confidence and what might help to increase their skills. Elementary teachers also need the appropriate teaching tools to educate K-5 students in STEM topics. Teachers in elementary education need professional development based on STEM content knowledge to gain the confidence in their content knowledge to educate students in STEM.

The preservice teachers' fluctuations in teacher leadership attitudes was interesting and warrants further investigations. The is a possibility that the preservice teachers thought about if and how they would teach other engineering lessons, and if it would have the same outcomes as these activities. Another factor could be that the preservice teachers thought about how they would teach these activities alone and if they can make their expectations known to their students. They did teach these lessons with other preservice teachers, so that could be a factor because they shared the leadership role. How does teaching engineering positively or negatively impact their how they view themselves as a teacher leader?

STEM career awareness is an important part exposing students to STEM, especially engineering fields where students do not always have a family member or role model. The study could include a section about the type of engineering careers in the world and what they do. How can STEM careers be included in the study while still making sure that the preservice teachers are still understanding engineering lessons and building their confidence in teaching it?

CONCLUSION

Attention must be given to teachers' cognitions, including their beliefs, intentions, and attitudes, when examining teachers' implementations of innovative reform (Capobianco & Rupp, 2014). Just as we worry about how students are feeling about learning and understanding the material presented to them, we must also make sure that teachers are comfortable and prepared for the material they are asked to incorporate. Engineering is incorporated with the science standards. At the elementary level, there are inconsistencies as to how often and for how long science is taught. The engineering design process relies on a gradual and continues development toward a solution (Lie et al, 2021). Everything is a process. There is work to be done from all sides.

While limited in scope, this study provided preservice teachers with essential engineering experiences both as students of engineering themselves and then as classroom facilitators of engineering activities aligned to NGSS. This study studied the impact these experiences had on preservice teachers' confidence, attitude, and self-efficacy toward teaching engineering in the classroom. While the results showed fluctuation in impact and some small decreases over time, looking at some of the individual questions provided interesting results that could be used to improve the engineering experiences of preservice teachers in future methods courses.

APPENDIX A: ENGINEERING ACTIVITIES

Blast Off

Your Names:
Blast Off

The Challenge:

Using the balloon and four cups, you will make a simple balloon rocket and test how you can achieve the **greatest** launch distance.

Note: Each member of the group will get their own materials and build their own rocket.

What you need:

- Scissors
- Cups: Styrofoam, paper, and plastic cups
- Double sided tape
- Balloons

Directions:

Build the Balloon Rocket:

1. Cut the bottom out of each cup.
2. Tape the round balloon inside the cup. Blow up the balloon.
3. Hold the end of the balloon closed. (DO NOT TIE THE BALLOON)
4. Hold the rocket towards the sky and countdown.
5. Ready to blast off!

Now that you built your balloon rockets, it is time to test them and see how you can improve them by having them launch further. Which cup is the best? What other factors affect the launch distance?

Each one of you will get four trials. After each trial, spend some time thinking of ways to **<u>improve</u>** your rockets and redesign them to make them launch further. Complete this table as a group (add your names in each trial and keep track of your progress).

Trial Number	Launch distance (from the slingshot)- Measure with the meter stick	Improvements made to your design (You can sketch, draw, take pictures, etc.)
Trial #1 *Add your names*		
Trial #2 *Add your names*		

Trial #3 *Add your names*		
Trial #4 *Add your names*		

Cotton Ball Launcher

Your Names:
Cotton Ball Launcher

The Challenge:

How can you send cotton balls flying with a toilet paper roll? How far can you do it? In this activity, you will design and build cotton ball launchers and see how far you can launch the cotton balls!

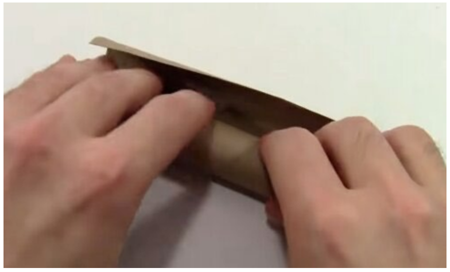
What you need:

- Pencils
- Rubber bands
- Toilet paper tube
- Strong tape
- Cotton balls/pom poms
- Meter stick

Directions:

1. Use your scissors to cut one of the toilet paper tubes in half lengthwise.

2. Squeeze the roll so that it becomes narrower, about half the original diameter, then tape it to hold in place.



3. Use your scissors or to punch two holes in the skinny tube (use scissors to make narrow holes the same shape as the pencil stick). Make the holes opposite one another, half an inch away from the end, so that you can poke your pencil all the way through the tube.
4. Carefully push your pencil or popsicle stick through the holes.

5. Grab another toilet paper tube, cut two slits into one end of the tube, about 1/4 inch long and 1/2 inch apart.
6. Cut two more slits on the same end of the tube, directly across from the first two.
7. On your second toilet paper tube, cut two slits into one end of the tube, about 1/4 inch long and 1/2 inch apart.
8. Cut two more slits on the same end of the tube, directly across from the first two.
9. Holding the rubber band tube so that the rubber bands are at the top, slide the narrower tube into the wider one with the pencil end at the bottom.
10. Carefully loop each rubber band end around the pencil.
11. Hold your launcher so that the pencil is at the bottom. Place the cotton ball on the top so that it rests inside the narrower tube.

12. Hold your launcher slightly horizontally without dropping the cotton ball.
13. Pull back on the pencil so that the inner tube extends two inches out the back of the launcher. Carefully aim your cotton ball---away from people.

14. Release the pencil and watch your cotton ball fly.

Now that you built your launchers, it is time to test them and see how you can improve them by having them launch further.

Each one of you will get three trials. After each trial, spend some time thinking of ways to **improve** your rockets and redesign them to make them launch further. Complete this table as a group (add your names in each trial and keep track of your progress).

Trial Number	Launch distance (from the launcher) - Measure with the meter stick.	Improvements made to your design (You can sketch, draw, take pictures, etc.)
Trial #1 *Add your names*		
Trial #2 *Add your names*		
Trial #3 *Add your name*		

Paper Flier

Your Names:

Paper Flier

The Challenge:

Can you create a flier that travels far? Let's find out!

What you need:

- Cardstock
- Paper
- Scissors
- Straws
- Tape

Procedure:

1. Cut two strips of cardstock for each end of the straw. Each strip should be about 1 inch wide.
2. Tape your strips to make two circles, one large one small.
3. Tape the circles to your straw.
4. You just made your first paper flier. You will be making two more. Keep reading!

Note: Each member of your group will make their own flyers and compare.
Now that you built your fliers, it is time to test them and see how far they fly! You will try out three different options for the sizes of the circles as shown in the table below.

Throw your flier three times and measure where the flier lands each time. Complete the table below. Write your names in each trial.

Circle Sizes	Launch Distance
Flier 1: Big and small *Your Names:*	
Flier 2: Big and big *Your Names:*	
Flier 3: Small and small *Your Names:*	

What improvements can you make to make your flier fly even further?

- Think about specific changes you can make and make a new flier. Add an additional row (or more) of your new design, identify what changes you've made, and test your flier again!

Popsicle Stick Catapult

Your Names:

Popsicle Stick Catapult

The Challenge:

In this activity you will build a catapult using simple items. You will investigate how you can hit a target using your simple catapult.

Materials for the Catapult:

- Popsicle sticks
- Rubber bands
- Plastic spoon
- Pom pom/plastic ball/bouncing ball

Materials for the Target:

- One large piece of paper (A3 or A2 paper works best). You can use a regular A4 printer paper.
- Black marker

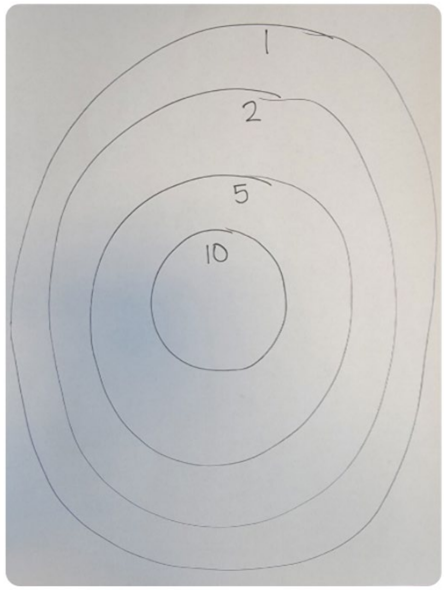
Procedure:

- Stack 5 ice cream sticks together.
- Tightly wrap a rubber band on each end of the stack.
- Stack the 2 remaining ice cream sticks together.
- Tightly wrap a rubber band around only one end of the stack.
- Separate the 2 ice cream sticks.
- Place the stack of 5 ice cream sticks between the 2 ice cream sticks.
- Place the plastic spoon on the top and attach the end of the spoon to the end of the top stick with a rubber band.
- Great Job! You built a simple catapult. Your catapult is now ready to launch objects!
- Experiment with your catapult and launch your object.
- Make sure any object you launch is soft and light. Make sure not to harm anyone or cause damage to objects around you.

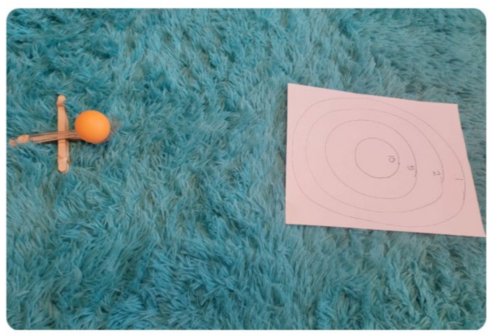
Note: Note: Each group member should build their own catapult.

Make a Target to Practice Launching

- STEP 1. On your large piece of paper, draw 4 concentric circles like in the picture.
- STEP 2. Add the numbers: 1, 2, 5, and 10 inside each circle like in the picture. These numbers are the scores of each circle.



- STEP 3. Position your catapult and the target paper on the floor. Sit or lay down on the floor behind your catapult.



Before you launch, think about:

- how you should position the catapult.
- the angle of the popsicle sticks.
- how far down you want to push the spoon.
- other variables that may help you hit your target.

Make sure to record all your findings and observations in the table provided below.

Note: Each group member should build their own catapult. Each member will have three trials.

The winner is whoever gets the highest total score!

Launch	Score (1, 2, 5, or 10)	Describe the variables you changed (You are free to make a completely new catapult!).

Trial #1 *Your Names:*		
Trial #2 *Your Names:*		
Trial #3 *Your Names:*		
Total Score		

Slingshot Straw Rocket

Your Names:
Slingshot Straw Rocket!

Challenge

Design and build small straw rockets and launch from YOUR slingshot. See how far you can launch your rockets!

What you need:

- Straws
- Paperclips
- Craft sticks
- Rubber bands
- Cardstock
- Masking tape
- Hot glue stick
- Meter Stick

Procedure (Each member in the group will build their <u>own</u> rocket. You will build only <u>one</u> slingshot).

<u>Building the Rockets:</u>

1. Cut a small piece of hot glue stick and tape it inside the straw
2. Open a paper clip
3. Tape the paper clip behind the glue stick (press down the tape tightly to secure the paper clip)
4. Cut out 3-4 fins with the cardstock paper
5. Tape both sides of each fin to the straw (leave space at the bottom of the straw)

<u>Building the Slingshot:</u>

1. Place tape on one side of the craft stick with half the tape hanging off
2. Place the rubber band at the end of the craft stick with the tape and fold the tape over
3. Add another piece of tape for security
4. To launch, pinch the back end of the straw and hold the craft stick as straight as possible
5. When releasing the rocket, tilt the craft stick forward to prevent the rocket from hitting the slingshot

Now that you built your rockets, it is time to test them and see how you can improve them by having them launch further.

Each one of you will get three trials. After each trial, spend some time thinking of ways to **improve** your rockets and redesign them to make them launch further. Complete this table as a group (add your names in each trial and keep track of your progress).

Trial Number	Launch distance (from the slingshot) - Measure with the meter stick.	Improvements made to your design (You can sketch, draw, take pictures, etc.)
Trial #1 *Add your names*		
Trial #2 *Add your names*		
Trial #3 *Add your names*		

APPENDIX B: Modified T-STEM Survey

Teaching Efficacy and Beliefs

Start of Block: General Information

Q1 What is your name?

____

Q2 Gender

oMale (1)

oFemale (2)

oPrefer not to say (3)

End of Block: General Information

Start of Block: Teaching Preference

Q3 Rank the grade in the order you would prefer to teach.

______ Kindergarten (1)

______ First grade (2)

______ Second grade (3)

______ Third grade (4)

______ Fourth grade (5)

______ Fifth grade (6)

______ Sixth grade (7)

End of Block: Teaching Preference

Start of Block: Teaching Efficacy

Q4 Please answer these questions based on your feelings about ***<u>your own</u>*** *teaching.*

	Strongly Disagree (1)	Disagree (2)	Neither Agreenor Disagree (3)	Agree (4)	Strongly Agree (5)
I am continually improving my engineering teaching practice. (1)	o	o	o	o	o
I know the steps necessary to teach engineering effectively. (2)	o	o	o	o	o
I am confidentthat I can explain to students why engineering experiments work. (3)	o	o	o	o	o
I am confidentthat I can teach engineering effectively. (4)	o	o	o	o	o
I wonder if I have the necessary skills to teach engineering. (5)	o	o	o	o	o
I understand engineering concepts well enough to be effective in teaching engineering. (6)	o	o	o	o	o

Given a choice, I would invite acolleague to evaluate my engineering teaching. (7)	o	o	o	o	o
I am confidentthat I can answer students' engineering questions. (8)	o	o	o	o	o
When a student has difficulty understanding an engineering concept, I am confident that I know how to help the student understand it better. (9)	o	o	o	o	o
When teaching engineering, I am confident enough to welcome student questions. (10)	o	o	o	o	o
I know what to do to increase student interest in engineering. (11)	o	o	o	o	o

End of Block: Teaching Efficacy

Start of Block: 21st Century Learning Attitudes

Q5 “I think it is important that students have learning opportunities to…”

	Strongly Disagree (1)	Disagree (2)	Neither Agreenor Disagree (3)	Agree (4)	Strongly Agree (5)
Lead others to accomplish a goal. (1)	o	o	o	o	o
Encourage others to do their best. (2)	o	o	o	o	o
Produce high quality work. (3)	o	o	o	o	o
Respect the differences of their peers. (4)	o	o	o	o	o
Help their peers. (5)	o	o	o	o	o
Include others' perspectives when making decisions. (6)	o	o	o	o	o
Make changes when things do not go as planned. (7)	o	o	o	o	o
Set their own learning goals. (8)	o	o	o	o	o
Manage their time wisely when workingon their own. (9)	o	o	o	o	o

Choose which assignment out of manyneeds to bedone first. (10)	o	o	o	o	o
Work well with students from different backgrounds. (11)	o	o	o	o	o

End of Block: 21st Century Learning Attitudes

Start of Block: Teacher Leadership Attitudes

Q6 “I think it is important that teachers …”

	Strongly Disagree (1)	Disagree (2)	Neither Agreenor Disagree (3)	Agree (4)	Strongly Agree (5)
Take responsibilit yfor all students' learning. (1)	o	o	o	o	o
Communicate vision to students. (2)	o	o	o	o	o
Use a variety of assessment data throughout the year to evaluate progress. (3)	o	o	o	o	o
Use a variety of data to organize, plan and set goals. (4)	o	o	o	o	o
Establish a safe and orderly environment. (5)	o	o	o	o	o
Empower students. (6)	o	o	o	o	o

End of Block: Teacher Leadership Attitudes

Start of Block: STEM Career Awareness

Q7 “I know …”

	Strongly Disagree (1)	Disagree (2)	Neither Agreenor Disagree (3)	Agree (4)	Strongly Agree (5)
About current STEM careers. (1)	o	o	o	o	o
Where to go to learn more about STEM careers. (2)	o	o	o	o	o
Where to findresources forteaching students about STEM careers. (3)	o	o	o	o	o
Where to direct student or parents to find information about STEM careers. (4)	o	o	o	o	o

End of Block: STEM Career Awareness

REFERENCES

Aranda, M. L., Lie, R., Guzey, S. S., Makarsu, M., Johnston, A., & Moore, T. J. (2020). Examining teacher talk in an engineering design-based science curricular unit. *Research in Science Education*, *50*(2), 469–487. https://doi.org/10.1007/s11165-018-9697-8

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education*, *97*(3), 369–387. https://doi.org/10.1002/j.2168-9830.2008.tb00985.x

Capobianco, B. M., & Rupp, M. (2014). STEM teachers' planned and enacted attempts at implementing Engineering Design-based instruction. *School Science and Mathematics*, *114*(6), 258–270. https://doi.org/10.1111/ssm.12078

Cartwright, Tina J. & Jon Atwood (2014) Elementary Pre-Service Teachers' Response-Shift Bias: Self-efficacy and attitudes toward science, International Journal of Science Education, 36:14, 2421-2437, DOI: 10.1080/09500693.2014.925152

Driessen, E.P., Dunn, A., Sallah, K., Wilhelm, J. & Cole, M. (2018). A Qualitative Study of Baseline Urban and Rural Middle Level Science Teacher and Student Views on Engineers and Engineering. International Journal of Environmental and Science Education, 13(7), 559-578.

Daily, S. B., & Eugene, W. (2013). Preparing the future STEM workforce for diverse environments. *Urban Education,* 48(5), 682 – 704.

Friday Institute for Educational Innovation (2012). *Teacher efficacy and attitudes toward STEM survey-elementary teachers*. Raleigh, NC: Author.

Hammack, R., Ivey, T. (2017). Examining elementary teachers' engineering self-efficacy and engineering teacher efficacy. *School Science and Mathematics*, *117*(1-2), 52–62. https://doi.org/10.1111/ssm.12205

Kelley, T. R., Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(11). https://doi.org/10.1186/s40594-016-0046-z

Lie, R., Aranda, M. L., Guzey, S. S., & Moore, T. J. (2019). Students' views of design in an engineering design-based Science Curricular Unit. *Research in Science Education*, *51*(3), 663–683. https://doi.org/10.1007/s11165-018-9813-9

Mangold, J., & Robinson, S. (2013). The engineering design process as a problem solving and learning tool in K-12 classrooms. *2013 ASEE Annual Conference & Exposition Proceedings*. https://doi.org/10.18260/1-2--22581

Moore, T. J., Glancy, A. W., Tank, K. M., Kersten, J. A., Smith, K. A., & Stohlmann, M. S. (2014). A framework for quality K-12 Engineering Education: Research and Development. *Journal of Pre-College Engineering Education Research (J-PEER)*, *4*(1). https://doi.org/10.7771/2157-9288.1069

Nadelson, L. S., Callahan, J., Pyke, P., Hay, A., Dance, M., & Pfiester, J. (2013). Teacher stem perception and preparation: Inquiry-based STEM Professional Development for Elementary Teachers. *The Journal of Educational Research*, *106*(2), 157–168. https://doi.org/10.1080/00220671.2012.667014

National Academy of Engineering and National Research Council. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects.* Washington, D: The National Academies Press.

National Academies of Sciences, Engineering, and Medicine. (2020). *Building capacity for teaching engineering in K-12 education.* Washington, DC: The National Academies Press.

Nesmith, S. M., & Cooper, S. (2021). Connecting Engineering Design and inquiry cycles: Impact on elementary preservice teachers' engineering efficacy and perspectives toward teaching engineering. *School Science and Mathematics*, *121*(5), 251–262. https://doi.org/10.1111/ssm.12469

Next Generation Science Standards Lead States. (2013). Next generation science standards: For states, by states. Washington, District of Columbia: National Academies Press.

Next Generation Science Standards. (2013). Read the Standards. Retrieved from http://www.nextgenscience.org

Perkins Coppola, M. (2019). Preparing preservice elementary teachers to teach engineering: Impact on self-efficacy and outcome expectancy. *School Science and Mathematics*, *119*(3), 161–170. https://doi.org/10.1111/ssm.12327

Porter, T., West, M. E., Kajfez, R. L., Malone, K. L., & Irving, K. E. (2019). The effect of teacher professional development on implementing engineering in elementary schools. *Journal of Pre-College Engineering Education Research (J-PEER)*, *9*(2). https://doi.org/10.7771/2157-9288.1246

Plans, A. (2015). The every student succeeds act: Explained. Education Week. Retrieved from https://www.ride.ri.gov/Portals/0/Uploads/Documents/Information-and-Accountability-User-Friendly-Data/ESSA/CoP/Education_Week_Every_Student_Succeeds_Act_Explained.pdf.

Schnittka, C., Bell, R., & Richards, L. (2010). Save the penguins: Teaching the science of heat transfer through engineering design. Science Scope. 34.

Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2017). How school context and personal factors relate to teachers' attitudes toward teaching integrated stem. *International Journal of Technology and Design Education*, *28*(3), 631–651. https://doi.org/10.1007/s10798-017-9416-1

The Engineering Design process. Science Buddies. (n.d.). Retrieved December 22, 2021, from https://www.sciencebuddies.org/science-fair-projects/engineering-design-process/engineering-design-process-steps

Trotskovsky, E., Waks, S., Sabag, N., & Hazzan, O. (2013). Students' misunderstandings and misconceptions in engineering thinking. International Journal of Engineering Education, 29(1), 107-118.

Yesilyurt, E., Deniz, H., & Kaya, E. (2021). Exploring sources of engineering teaching self-efficacy for pre-service elementary teachers. International Journal of STEM Education, 8(1), 1-15.

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