UNIVERSITY OF THE Arts

Developing an Elementary STEM Class and Curriculum

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree

Master of Education
Educational Program Design/Educational Technology

May 13, 2023

Abstract

This thesis reviews literature focused on researching the outcomes of STEM education and educational experiences for elementary school students. The research is then applied to the five-unit curriculum focused on engineering for students in kindergarten through fifth grade. The curriculum is structured for every student to receive 15 class meetings per school year. The six year program is intended to improve students' awareness of the 21st Century Skills of creativity, critical thinking, collaboration and communication. The curriculum is also guided by the Pennsylvania Department of Education's recently released STEELS Standards. These standards address the content of Next Generation Science Standards as well as competencies in the areas of engineering, design and technology. The curriculum includes a variety of challenges and opportunities for students to experience problem based learning in order to apply design thinking and the engineering Design Process.

Keywords or Terms: STEM, Engineering Design Process, 21st Century Skills

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Chapter 1: Introduction

Science, technology, engineering and math (STEM) education at the elementary school level has proven to have an array of benefits for students. Research has found a clear correlation between STEM experiences and positive student attitudes (Slim et al., 2022). STEM activities resulted in student improvement in defining and solving problems (Lin et al., 2016). And, most importantly to an elementary school system, exposure to STEM is most impactful in earlier grades (Chiang et al., 2020).

The Pennsylvania Department of Education, in which this researcher's work is based, has greatly acknowledged the need of STEM education in elementary schools with its recent release of Science, Technology, Engineering, and Environmental Literacy and Sustainability (STEELS) standards that will be expected of all kindergarten through 12th grade students in coming years. These standards, which include novel competencies in an array of STEM skills, require school systems to implement STEM education at the elementary level.

Ensuring that STEM will be included in the education of all elementary school students is vital to equipping students with the mindset, abilities and 21st Century Skills needed for success. Determining the outcomes, learning plan, and other logistics of a STEM program is a daunting task, but the results justify the effort.

Problem Statement

With the release of the new STEELS standards and the down to the minute schedule that already exists within elementary schools it may be challenging to implement a STEM curriculum that is (a) available and equitable to all students, (b) cost effective and (c) capable of meeting a set of vertically aligned standards. To ensure

successful opportunities for STEM, a school system must consider how much time is needed for STEM education, what the crucial elements of STEM in an elementary school setting are, and how schools create a curriculum for specialized STEM education within those constraints.

Significance

The research presented here has led to the determination that a kindergarten through fifth grade stand-alone STEM class will aid in creating an entire student body equipped with determination and the 21st Century Skills needed to solve problems in and out of the classroom. The structure and exact logistics of the class may vary from school to school or district to district, but school systems should invariably incorporate two specific elements in their STEM curriculum to attain both academic and mindset gains. These two elements are: engineering and coding. Engineering instruction, rooted in having students employ the Engineering Design Process (EDP) and computer science lessons, focused on coding, have been proven to enhance and benefit students' attitudes, academics and 21st Century Skills. This curriculum, with learning outcomes informed by PDE's STEELS standards, addresses the engineering component of STEM. The curriculum and class is intended to provide an opportunity for all students to thrive by fueling imagination, engagement, curiosity and perseverance while working in a collaborative environment guided by the EDP.

Definition of Terms

STEM: The integration of science, technology, engineering and mathematics as integrated area of study

Engineering Design Process: A series of steps to be completed as a method of solving engineering related problems. The steps include: Ask, Imagine, Plan, Create, Improve, and Communicate

21st Century Skills: A set of skills that are widely accepted as necessary for success. For purposes of this thesis, the skills that are recognized are: Creativity, Critical Thinking, Collaboration, and Communication. These are often referred to as the 4 C's

Coding: creating programs for computers and robotic devices

Chapter 2: Literature Review

In his 2011 State of the Union Address, President Barack Obama put forth a goal to add 100,000 STEM teachers to America's classrooms in 10 years (https//:www.obama.org). According to the Obama Foundation website, this goal was not only met last year, but exceeded. The Foundation reports that just over 108,000 teachers trained in science, technology, engineering and mathematics (STEM) have joined the K-12 teaching ranks in our country (https//:www.obama.org)**.** For those in education today, this growth can be easily seen at the high school level. Tech Centers have been opened or updated so that students are able to graduate from high school with training for careers in STEM fields. Greater access to math and science classes has also been provided for students. High schools have partnered with local colleges and universities to allow students to pursue college credits during their high school years by accessing college course catalogs and begin their pursuit of STEM degrees before their high school graduation.

Looking into the lower grade levels, particularly the elementary grade levels, there is still more to be done to create a true implementation of STEM education for all students. There are certainly some pockets of STEM moving into elementary schools, but there is not yet STEM for all. Elementary schools, tasked with teaching the basics of reading, writing, and math, still have not fully embraced the commitment to STEM beyond the science and math bookends to the acronym.

Based on observation, STEM has been "pushed in" the elementary school setting by many different programs. Educational agencies, such as the Intermediate Units found in Pennsylvania, have provided resources for educators including

professional development and opportunities for student enrichment in STEM activities. Private programs, both businesses and non-profit organizations, work with elementary schools to provide learning opportunities and experiences outside of the school day. There are educational programs that can be purchased by schools or school systems that offer pre designed units of interdisciplinary projects that can be tied to existing math or science curricula. These programs offer students opportunities to explore a deeper STEM experience that goes beyond math and science, but they are often expensive and require replacement of materials from class to class or year to year. For elementary school systems to make a true commitment to STEM education that is equitable to all students, cost effective and vertically aligned to truly build student capacity, school districts must create and implement a STEM curriculum. The purpose of this literature review is to answer questions regarding the development of an elementary STEM curriculum. First, what are the benefits of implementing STEM education, specifically a stand alone STEM class, in an elementary school setting? Second, what are the crucial elements to an exemplary kindergarten through 5th grade (K-5) STEM curriculum? And finally, how do you design a K-5 elementary curriculum for a specialized STEM class?

The Benefits of Implementing an Elementary School STEM Curriculum

When investigating the beneficial attributes of any program for elementary aged students there is no perfect method of research. Whether researching the costs or benefits of any instructional, academic, social, or athletic program for children, qualitative and quantitative data must both be gathered. The research discussed and analyzed in this review will look for the quantitative data related to student performance

in academic assessments. Research has identified specific academic areas where exposure to STEM learning experiences is related to student aptitude. There is also research that points to qualitative growth in student attitude and performance in non-academic areas. The benefits toward student attitude and outlook can not be understated in an elementary education setting and we will be examined first.

Research completed and published by Tessa Slim and her team from the University of Amsterdam in 2022 used both qualitative and quantitative measures to research the impact of STEM learning experiences on students that were known to have a varied academic abilities, attitude, and different levels of executive functioning. According to the findings of Slim et al., STEM education was able to bring students with lower test scores and a negative attitude towards school up to the level of their higher performing counterparts. These students, who were predicted to perform poorly due to their assessed abilities and attitudes, were reported to have had just as many positive opinions on their learning experience as their better prepared counterparts (Slim et al., 2022). Although they still underperformed in quantitative academic post-tests, the influence of design based learning was a positive factor on their attitude towards science and technology on those with lower scores in the aptitude testing. Similarly, Jose Manuel Sâez Lopez and his team from Madrid found that students “showed enthusiasm, motivation, a sense of fun and actively participated” in a STEM centered learning environment (Sáez et al., 2021). His team also noted a “sense of perceived usefulness” in their experimental group. This “usefulness” can be interpreted as a positive factor in student attitude towards learning. To close the discussion of STEM’s impact on student attitude, research by Feng-Kuang Chiang, Chun-Hao Chang, Shan

Wang, Rui-Heng Cal and Li Li of Shanghai Normal University brought to light a very important detail. Academic gains continued through the grade levels for students exposed to STEM, but the effect STEM can have on attitude may be most impactful in earlier grade levels. They found that as students aged, the impact of STEM on student attitude waned. The sixth graders studied in Beijing demonstrated exceptional growth in the area of mathematics, especially in their first semester. However, the attitude measure that was assessed by the questionnaire showed fourth grade students were most affected by the STEM course (Chiang et al., 2020). The impact that STEM, in various formats and with varied regularity, has had on the attitude, engagement and motivation of students at the elementary level has been clearly demonstrated by the research presented here. Incorporating STEM as a class for all, not just an extracurricular experience for some, will have a positive impact on a school system by improving attitude.

Understanding that most educational systems would not make the commitment to a K-5 STEM program based on improved student attitude alone, there must be evidence of student gains in academic achievement. To put it simply, STEM learning experiences have been shown to be a factor in many aspects of student performance. Lyn English of Queensland University states that students who have been described as “low achieving” frequently show surprising gains in academic testing following exposure to student centered STEM activities (English, 2017). She states, in her own research and in review of others, that a student’s floor and ceiling for learning, especially in math, can be raised by STEM designing activities (English, 2017). Kuen-Yi Lin and a team of researchers from Taiwan were able to identify gains in performance of their research

subjects in all variables that they studied (Lin et al., 2021). Lin's team stated that their experimental group was better able to define problems and estimate solutions, which are key to solving problems in math and science (Lin et al., 2021). This positive effect on problem solving abilities is mirrored in research completed by Yanyan Li and a research team from Beijing. They found that fourth grade students who completed Lego STEM activities with an engineering focus showed a significantly stronger ability to identify optimal solutions to problems at hand (Li et al., 2016).

Through careful analysis of the research that has described the benefits of STEM education, one can find commonalities in the gains in student performance. There are clear gains in the well documented 21st Century Skills: Critical Thinking, Creativity, Collaboration, and Communication. All of the research presented here has shown a connection between STEM education and a student's ability to define problems, imagine, plan and evaluate possible solutions. The Critical Thinking and Creativity needed to move from problem identification to original solution can aid students in all academic areas. The Collaboration and Communication required to complete these activities within a group setting go beyond what can be scored on an academic assessment. These skills are not discrete or meant to be confined within any one subject area, but will aid student performance during and after their elementary education. Research will need to be done in the future, but one could hypothesize that elementary STEM education will have a positive impact on academic achievement during the middle and high school years.

Crucial Elements of STEM Education

In examining previous research on STEM education, it is imperative to note that in nearly every case study, experiment, or survey presented in this literature review the STEM experiences created for research were not available to an entire school system. STEM continued to be outside of the learning environment offered to all students. The creation of a STEM Class for every student is the foundational stone that is crucial to successful implementation of STEM education. English wrote "well designed STEM and STEAM experiences can provide learning affordances that enable the engagement of a more diverse range of students," (English, 2017). English also put forth the idea that STEM may not be available to some because schools have not been able to create a time or space for all disciplines to be represented. A hierarchy exists where math is prominent and science and technology are taught to a lesser extent, but engineering is absent (English, 2017). By creating a space for engineering, educational program designers may be able to bring STEM education to everyone while incorporating one of the most crucial elements of STEM education: Design Thinking and Problem Solving using the Engineering Design Process (EDP).

Engineering projects and activities are an ideal option for teaching Design Thinking and the Engineering Design Process. The process has been employed in much of the research presented in this review. Engineering projects with an emphasis on the EDP were at the forefront of research that was completed by Justin McFadden and Gillian Roehrig from the University of Minnesota. Their case study found that when students were given a framework to define, analyze, and plan a prototype to meet the needs of an engineering challenge, the students were able to build the prototype and

subsequently describe their work (McFadden & Roehrig, 2019). In other activities, when only presented the opportunity to draw plans, student discourse and description of the work was negatively impacted. Though McFadden and Roehrig did not name the Engineering Design Process in their writing, they clearly described a process based on the EDP. Lin et al., who actually used teacher's training in the EDP as a variable in their research, point decisively to the EDP as crucial to reaping the benefits of STEM education. As previously mentioned, the authors stated that instruction in the use of the EDP improved the performance of the research subjects in all variables (Lin et al., 2021). The authors, in fact, tie the Engineering Design Process and Problem based learning to all aspects of their experimental group. Teachers were instructed in the EDP and the instruction was passed along to their students resulting in improved performance for all. In comparison, The Slim research team did not necessarily identify the EDP as part of their design instruction. They did, however, in their description of their first four learning sessions, describe activities that mirror the EDP. Students were asked to define the problem, imagine and experiment with possibilities, and plan and create a musical through the first four lessons (Slim et al., 2022). These activities correlate to the EDP's first four steps: Ask, Imagine, Plan and Create. As students move through these and the remaining steps of the EDP, Improve and Communicate, there is ample opportunity for learning experiences that enhance students' abilities in the 21st Century Skills. These skills will be expanded upon later in this work as the framework for a STEM curriculum is laid out.

Engineering instruction, rooted in the EDP, can clearly stand as a crucial element to STEM education, but there is another STEM discipline that can be explored and is

also proven by research to be beneficial to students' attitudes, academics, and development of 21st Century Skills. Coding falls squarely under the Technology aspect of the STEM acronym and has been at the center of much of the research reviewed. Coding has not only proven beneficial to students through this research, but it can be used by school districts as a basis for learning opportunities that address newer and ever evolving standards in computer science (CS) education. The development of a STEM class and STEM curriculum can and should include coding as one of its crucial elements.

In 2019, Peter Rich and a team of researchers from Brigham Young University conducted a survey among 300 teachers from around the globe. The purposes of their survey were to determine what types of computing/coding were being taught around the world and what were the outcomes, positive or negative, of coding instruction being implemented in the K-8 environment. Their findings on what was being taught will be discussed later. The outcomes and reactions to coding instruction were overwhelmingly positive, from academic growth to stakeholder support and enthusiasm. Rich et al. presented a very straightforward and clear representation of the problem solving skills students can improve through coding instruction (Rich et al., 2019). The authors included many reasons coding instruction has been identified as a factor for the improved problem solving skills. They found that students were able to improve breaking problems down into manageable parts, recognize the possibility of multiple solutions, develop grit, and find logical approaches to solving problems (Rich et al., 2019). The Brigham Young team also found that coding teachers believe that their instruction is very well received by the stakeholders in their school system. Over 70%

of respondents report that their students “love it” and that is also true for nearly 50% of supervisors (Rich et al., 2019).

Coding also opens the door to bringing robotics into the classroom. Robotics has been proven to provide opportunities to teach the same problem solving behaviors, 21st Century skills and computer science standards in a highly motivating environment. Mor Friebroon-Yesharim and Mordechai Ben-Ari of the Weizmann Institute of Science published their study of second graders learning computer science principles in a robotics based course. The research team began their study in response to the idea that teaching computer science to young elementary school students is difficult due to students’ inability to engage with and grasp sequential and logical imperatives that define computer science (Yesharim & Ben-Ari, 2018). Their research showed that students were able to learn CS, with some limitations, using the robots. The one aspect that seemed to be beyond the second graders grasp was writing and constructing their own programs (Yesharim & Ben-Ari, 2018). This information, with the understanding that students were motivated and engaged in the study, provides curriculum designers and writers with a guide for creating essential understandings that are appropriate for elementary students.

While Yesharim and Ben-Ari found that second graders could not write programs, even with the addition of robotics, Sáez Lopez and the research team from Madrid found that fifth graders were able to use robotics and coding languages to construct programs using sequences, loops, and conditional statements (Sáez et al., 2021). The experimental group in this study also showed significant progress in math, computational concepts and classroom interaction (Sáez et al., 2021).

Whether using robots or other coding mediums, schools interested in incorporating problem-based learning (PBL) can look to a STEM class with a coding component embedded in the curriculum to provide motivating opportunities to teach CS. A study by Kwon et al. from Indiana University used pretest and post-test data from 200 sixth grade students to measure student learning outcomes as well as a likert scale, a survey used to measure students' attitude. There were multiple outcomes determined to be relevant by the study's authors. The research team's findings indicate that there are coding principles that are more easily learned and retained than others. They also determined that students with greater levels of prior knowledge learned more and retained more than those lacking in prior knowledge. The students lacking prior knowledge did, however, close the gap on students with more prior knowledge as evidenced in the post-test data (Kwon et al., 2021). This research, combined with the works of other researchers demonstrate that coding can and should be taught to all students, not just those who join after school programs. The STEM class for all students with an informed curriculum will make this possible.

K-5 STEM: Beginnings of Curriculum Design

To ensure that the development of a kindergarten through fifth grade curriculum is truly effective in instilling and improving 21st century skills within students, curriculum writers can turn to the work of Grant Wiggins and Jay McTighe. Understanding by Design, the curricular planning framework developed by Wiggins and McTighe in the early 2000's provides a structure for curriculum design that is meant to ensure that students are able to "transfer learning" from a classroom to any setting and use discrete

knowledge and skills in multiple contexts (Wiggins & McTighe, 2005). The Understanding by Design model explicitly orders the steps or stages of curriculum development to transform content standards into focused learning targets, assessments and activities to allow for that authentic learning that can be transferred (Wiggins & McTighe, 2005). The three stages identified and discussed by Wiggins's team are: identifying the goals of learning, identifying the evidence that will determine if goals have been met, and designing the plan for activities that will be used to achieve goals to the level of knowledge transfer (Wiggins & McTighe, 2005). The purpose of this literature review now shifts to utilizing the research of STEM education and 21st century skills to answer Wiggins's essential questions at each stage of curriculum development.

Wiggins and McTighe demand that curriculum writers first define what students should be able to do and what they should understand as a result of the class or experience provided to them (Wiggins & McTighe, 2005). The curriculum team must identify the goals for the course. As discussed earlier, research has shown that engineering and coding are elements of the STEM acronym that are not typically covered in elementary school curriculums, but have proven beneficial to student learning, problem solving abilities, and attitudes and motivation to participate in their education. To faithfully complete Wiggins's Stage One, curriculum writers would be tasked to "Unpack the Goals" that are found within content standards for both engineering and coding (Wiggins & McTighe, 2005). According to much of the research presented in this review, the Engineering Design Process must be considered an essential goal for students. The Engineering Design Process can be used in both engineering and coding portions of the STEM class and can be carried and transferred

into other classes and facets of a student's education. As discussed earlier, the group led by Lin found that specifically teaching the Engineering Design Process improved the performance of the subjects of the study in all variables that were examined (Li et al., 2021). Stage One of Understanding by Design would not be complete without including knowledge of the Engineering Design Process as a specific understanding students should be taught and able to transfer and follow on their own.

Another goal of the STEM course is for students to advance their proficiency in application of 21st century skills: critical thinking, creativity, collaboration and communication. The Engineering Design Process can be used as a template for teaching these skills with a project based learning approach or a design based approach. Returning to the findings of Lin's team, their experimental group, who was instructed using the Engineering Design Process, was better able to define the problem and better estimate the effects of varying factors in the performance of their prototype (Lin et at., 2021). The researchers go on to state that there is an improvement in creativity and critical thinking and engineering-related courses improve sophisticated thinking (Lin et al, 2021). In the case study completed by McFadden and Roehrig, the researchers noted that when creating prototypes and utilizing design thinking there was significant increase in student discourse and collaboration (McFadden & Roehrig, 2019). A STEM course that already has identified the Engineering Design Process as an essential goal seems to naturally fit as an opportunity to improve on 21st century skills.

There are also some "big ideas", as Wiggins would describe them, that are specific to engineering. Engineering activities have been proven to be successful in

developing knowledge of science standards and promoting successful transfer of science knowledge. A study conducted by Yuyun Maryuningsih and a research team in Indonesia that was working to investigate assessment of 21st century skills concluded that students were able to better share information and experiences in discussions after engineering activities (Maryuningish et al, 2020). Incorporating science standards and engineering practices is clearly done in the Next Generation Science Standards (NextGen). In searching any science standard on the NextGen website, there are engineering practices described to be used in teaching the standard (https://www.nextgenscience.org/). Lyn English comments directly on the NextGen Standards when the researcher states, “transdisciplinary approaches encompass knowledge and skills learned from two or more disciplines applied to real-world problems and projects, thus shaping the total learning experience” (English, 2017). As this research suggests, Stage One of Understanding by Design can not be completed for the engineering component of a STEM curriculum without the inclusion of science standards.

In looking at the coding portion of the STEM curriculum, there are other pieces that need to be identified during Stage One of Understanding by Design. According to a global research team assembled by Mary Webb, any curriculum focused on computer sciences must include an early introduction for students to “three major types of knowledge: concepts, propositions and know how” (Webb et al, 2017). To work into Wiggins’s Stage One, the concepts need to be identified. As mentioned earlier, Kyungbin Kwon’s team researched the effectiveness of a block-based coding curriculum. They researched a variety of coding concepts including sequencing, loops,

conditionals, events, and variables (Kwon et al, 2021). According to their research, sequence and loops are the concepts to begin with (Kwon et al, 2021). With the concepts identified, curriculum writers are then on to Stage Two.

Understanding by Design starts Stage Two by asking what evidence must be collected and assessed to analyze the accomplishment of goals in Stage One (Wiggins & McTighe, 2005). The fact that a STEM class will be mainly utilizing project and design based learning makes for complicated collection of assessment evidence. Due to the fact that learning goals include the Engineering Design Process and the application of 21st century skills, the evidence of learning will be found more in the process of an activity rather than the outcome. With this in mind, methods of assessment must be developed to be completed during the completion of a project. Dick Arends and Ann Kilcher's chapter Classroom Assessment, provides a strategy that can be employed to meet the needs of Stage Two. Learning as Assessment offers multiple forms of self and peer assessment that can be utilized to collect the evidence of learning that is needed in Understanding by Design (Arends & Kilcher, 2010). Ideas such as Learning Logs, Pre-Flight Checklists, and Two Stars and a Wish that are presented by Arends and Kilcher provide a format for assessment (Arends & Kilcher, 2010). These assessment activities are opportunities for students to assess themselves and other teams before, during and after a project to allow opportunities for critical thinking. Researchers Binar Ayu Dewanti and Agus Santoso provide the indicators that can be used to effectively assess 21st century skills. They have developed a rubric that lists Communication, Collaboration, Critical Thinking, and Creativity as the skills they intend to assess. They move on and list indicators for each skill and construct rubrics for both Project and

Performance Based assessment in STEM based science projects (Dewanti & Santoso, 2020). The indicators will need to be adjusted for elementary aged students, but their method was proven to be valid and effective (Dewanti & Santoso, 2020). The work of Dewanti and Santoso can be moved further by the Maryuningsih and the research team that analyzed 21st century skills in online discussion activities. Their domains and indicators were applied only to communication between students in online formats, but can be transferred to in person learning settings (Maryuningsih et al, 2020).

Having investigated necessary components for Stages One and Two of Understanding by Design, curriculum writers and teachers are now tasked with creating and aligning learning activities for engineering and coding projects in the elementary STEM classroom. This final step, the development of the learning plan, is where educators must ask themselves if the work is engaging and effective (Wiggins & McTighe, 2005). Nearly all of the research presented in this review found that students were both engaged and positively affected by exposure to STEM learning. Referring once again to Chiang et al, the authors found that STEM classes and engineering activities had a positive impact on both students' attitudes and growth of problem solving skills (Chiang et al, 2022). Coding activities, especially with robots, created student gains in math scores and enthusiasm towards school (Saez et al, 2021). The research has demonstrated that educators and curriculum writers, once they have identified their instructional goals and assessment evidence, should be able to construct learning activities that meet the standard of engagement and effectiveness (Wiggins & McTighe, 2005).

Conclusion

The creation of an exemplary elementary STEM curriculum for a stand alone STEM class will be an important addition to the kindergarten through fifth grade school setting. By offering opportunities for students a thorough, well planned curriculum rooted in engineering and coding, school systems will be able to meet ever evolving standards, such as PDE's new STEELS standards. The positive effects on student attitude, motivation, and problem solving will resonate to other subject areas. Students will make gains not only in math and science, but will also improve their application of 21st century skills including critical thinking, creativity, collaboration, and communication.

Chapter 3: Curriculum Overview

The curriculum and learning plan presented in this thesis is an innovative and novel elementary school program that addresses school, district and state goals for student skill development and achievement in multiple areas. The curriculum provides opportunities for growth in 21st century skills, character development, growth mindset, science standards, and computer science skills. There are a variety of short term goals that are aligned with Next Generation Science Standards, Pennsylvania's Integrated Standards for Science, Environment, Ecology, Technology, and Engineering, and the Pennsylvania Department of Education's Computer Science Standards. There are also long term goals that aim for students to develop and utilize design thinking and processes as well as the recognized 21st century skills of creativity, critical thinking, collaboration and communication. The STEM curriculum will provide critical time and opportunity for elementary school students to accomplish that mission.

The curriculum is intended for students in grades kindergarten through fifth grade. Schools implementing this curriculum would include STEM as part of their specials or exploratory rotation. STEM is offered to students once per six-day cycle in this curriculum framework. Each class session is 45 minutes in length and there are 30 sessions in each grade level. There are two separate curriculums covered in each school year. The curriculum presented in this document is the engineering curriculum. The companion curriculum is dedicated to coding. The curriculums are organized so that students will receive 15 class sessions dedicated to Engineering and 15 sessions dedicated to Coding. Students in primary grades, kindergarten through second grade, will begin each year with Engineering, while secondary students, third grade through

fifth, will begin with Coding. It should be noted that all students will truly begin the year with one engineering activity that will be focused on collaboration and growth mindset.

For those who would evaluate the curriculum and the course itself, it should be noted that the curriculum is guided through the Understanding by Design (UbD) framework first introduced by Grant Wiggins and Jay McTighe in 2005. The learning outcomes and goals are a blend of 21st Century Skills, the Engineering Design Process and standards recently released by the Pennsylvania Department of Education as the STEEL Standards. The course's primary function is the development of 21st century skills. The students are meant to be active participants and drive their own advancement towards independence in those skills. The course and curriculum is designed for students to understand and apply the EDP. Evaluators should find evidence that the students are capable of monitoring their own progress through the EDP. As far as instruction and learning that targets the STEELS standards, students will be able to provide and demonstrate evidence mainly in those standards relating to Engineering and Technology. These standards are presented by the Department of Education in three year bands. Students are to progress through the primary standards in grades kindergarten through two and then the secondary standards in grades three through five. Assessments and assignments should allow for students to present and evaluate their own evidence of proficiency in these standards, especially by grades three through five. Finally, evaluators should see evidence of the more traditional science standards in student's vocabulary and understanding of their engineering work. These science standards will not be assessed in the STEM class, but they will be

explored to add depth to students' understanding that will allow for greater success in their science classrooms and assessments.

ELEMENTARY STEM CURRICULUM

STEM ENGINEERING UNITS

Subject	STEM	Grade Level	K-1
Title of Unit	Engineering Unit 1	Time Frame	15 Class Meetings per School Year

Stage 1 - Desired Results

Established Goals & Learning Outcomes
The desired results for the STEM Engineering Units in all grade levels will be a combination of skills, learning dispositions, and standards. Skills and habits of mind such as the 21st Century Skills of creativity, critical thinking, collaboration and communication will be woven and infused into learning activities along with PA STEELS Standards and Practices, and Next Generation Science Standards.

Learning Outcomes

1. Students will develop an understanding of the engineering design process.
2. Students will develop the ability to apply the engineering design process.
3. Students will develop perseverance through trial and error and experimentation.
4. Students will develop an understanding of and be able to apply the 21st Century Skills of creativity, critical thinking, collaboration and communication.
5. Students will develop an understanding of and be able to use online communication platforms.

PA STEELS Standards

1. 3.3.K.C- Use a model to represent the relationship between the needs of different plants or animals (including humans) and the places they live
2. 3.2.2.A Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties
3. 3.2.2.B Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose

4. 3.5.K-2.K- Safely use tools to complete tasks
5. 3.5.K-2.M- Demonstrate essential skills of the engineering design process
6. 3.5.K-2.N- Analyze how things work
7. 3.5.K-2.O- Illustrate that there are different solutions to a design and that none are perfect
8. 3.5.K-2.Q- Apply skills necessary for making in design
9. 3.5.K-2.S- Apply design concepts, principles, and processes through play and exploration
10. 3.5.K-2.V- Explain that materials are selected for use because they possess desirable properties and characteristics
11. 3.5.K-2.DD- Collaborate effectively as a member of a team
12. 3.5.K-2.CC- Discuss the roles of scientists, engineers, technologists, and others who work with technology

Transfer
Students will be able to independently use their learning to … ● Persevere through challenging problems while demonstrating a Growth Mindset. ● Demonstrate adaptability in order to apply Design Thinking to solve problems. ● Utilize the engineering design process for a variety of problems. ● Conduct tests/experiments to analyze structures and materials. ● Approach problems with curiosity and creativity. ● Compare, contrast and evaluate possible solutions for problems by thinking critically. ● Collaborate with others in various roles. ● Utilize written and spoken communication methods in order to explain thinking, planning, and problem solving processes. ● Ask questions to clarify their understanding of a concept. ● Create models for a variety of purposes.

<table>
<tr><th colspan="2">Meaning</th></tr>
<tr><th>Enduring Understandings</th><th>Essential Questions</th></tr>
<tr><td>Students will understand that...
The engineering design process begins with imagination and planning before creating.
Building materials can vary in many ways and these factors may determine the effectiveness of a material. Ex. Strength, Durability, Buoyancy
Shapes and structural choices play a role in building.
Models can be utilized to solve problems and as means of demonstration.
Communication and collaboration are critical for success.</td><td>Students will keep considering….
How do engineers use the design process to solve problems?
What can team members do to help the group or team?
How do materials and shapes affect a project?
How can building a model help solve a problem?
How can I communicate my thinking and ideas?</td></tr>
<tr><th colspan="2">Acquisition</th></tr>
<tr><td>Acquisition of Knowledge</td><td>Acquisition of Skills</td></tr>
<tr><td>Students will know...
The engineering design process can be used to solve problems and involves using creativity and planning to create solutions.
Properties of materials affect the success of a building project and must be considered prior to building.
Creativity, critical thinking, collaboration and communication are essential to engineering success.</td><td>Students will be skilled at....
Using a variety of materials and techniques to create models or structures.
Using age appropriate tools safely and correctly.
Perform roles that contribute to the success of a team.
Communicate through a variety of methods including creating an online portfolio of work samples and artifacts.</td></tr>
</table>

Stage 2 –Evidence

Performance Tasks

- Icebreaker/partner practice activities and challenges
- Create a Lego playground using the engineering design process
- Marshmallow and toothpick structures using a variety of shapes
- Contraption Lab marble runs
- Zoo Design
- Kindergarten Boat investigation and build using the engineering design process
- First Grade Robot Construction using the engineering design process
- Variety of holiday themed performance tasks

Other Evidence

- Observation
- Online Portfolio Artifacts
  - Photos of design stages, including final product
  - Videos (products and reflections)
- Peer Reviews
  - Pre-Flight Checklists
  - 2 Stars and a Wish

Student Self-Assessment

- Individual and Team reflection videos
- Self Assessment Rubric
- Pre-Flight Checklists
- 2 Stars and a Wish

Stage 3 –Learning Plan
Sequence and Description of Performance Tasks and Design Challenges

Collaboration and Partner Practice Activities- Can be used as icebreakers and set the foundation for collaboration in the STEM Classroom (2-4 Class Sessions)

- Ten Apples Up On Top Challenge
    - During reading of text, discuss the collaboration of the three main character as they work towards 10
    - Have students build creations to hold apples. Materials and specific structure can be modified to accommodate students. Beginners may build towers with Lego, developing students may used cardboard, recyclables, etc. Independent students may use recycled materials to build hats holding apples.
- Binder Ring Web Challenge
    - Students will work in teams to use string tied to a binder ring to lift an object.
    - Accommodations can be made by varying the size of teams, size of binder ring, or the object being raised.
    - Team members should be rotated for "rounds" of the challenge.
- Variety of Lego Challenges
    - These may be inspired by multiple books, characters or scenarios. Example: Build a new space craft for Buzz Lightyear
    - Quick 20 minute challenges focused on collaboration
    - Opportunity to introduce Seesaw or other online portfolio for photographic artifacts of design challenge

Playground Design (2 Class Sessions)

- The engineering design process is introduced and used by students to create playgrounds. Individuals will design and create a single piece of playground equipment. Collaboratively, the team will create a complete playground.
    - Accommodations can be made by varying building materials. Kindergarten will work with legos, first graders may be allowed a choice of materials including legos, paper tubes, straws, pipe cleaners, etc.
    - Students will add artifacts to online portfolios.
    - Preflight checklist can be used as formative assessment before building.

Marshmallow/Toothpick Structures (1 Class Session)

- Students will use marshmallows and toothpicks to make small houses.
    - Students will be asked if shapes used by engineers make a difference in building.
    - Students will determine that triangular shapes are typically stronger than squares.

Marble Runs with Contraption Lab (1 Class Session)
- Students will work in teams to use the engineering design process to build marble runs that take 10 seconds or more to complete.
  - Students will use timers and create videos of marble run.
  - Self assessment rubrics may be used.

Zoo Design (2 Class Sessions)
- Students will work in small teams to build zoo habitats that will provide animals with necessities for a quality life.
  - Accommodations may be made with building materials. Lego may be used for learners that are still developing skills. Cardboard and recycled products can be used for more independent students.
  - All stages of the engineering design process will be represented in student's work with an emphasis on ASK. Students will be required to respond to what was needed in their design for animal's survival.

Robot Design and Build 1st Grade (5-6 Class Sessions)
- Students will work through the engineering design process to imagine, plan and build a cardboard robot that is designed for a specific purpose.
  - Students will independently plan their own and then work collaboratively with a partner to build their design.
  - Online portfolios will be used to document steps of the design process.
  - 2 Stars and a Wish will be completed as a summative assessment of the project.

Boat Design and Build Kindergarten (4 Class Sessions)
- Students will learn about the properties of materials and design and build a boat using the engineering design process.
  - Curious George and the Boat Show will be read and referred to during design.
  - Students will test materials for sink or float capabilities.
  - Students will build foil boats to gain exposure to weight distribution and surface tension.
  - Students will work collaboratively to build a boat.

Additional Challenges and Activities
- Free STEM Classes
  - Students will be able to work with a variety of building materials or STEM tools. Choices may include: Lego, Cup Towers, Block, Box Forts, Contraption Labs, Design and Draw
- Holiday or Special Activities
  - Halloween- Build With Bones (Marshmallows and toothpicks)
  - Thanksgiving- Balloons over Broadway
  - Christmas- Rocket Sleigh
  - St. Patrick's Day- Leprechaun Trap

Subject	STEM	Grade Level	2
Title of Unit	Engineering	Time Frame	15 Class Meetings
Stage 1 - Desired Results			

Established Goals & Learning Outcomes
The desired results for the STEM Engineering Units in all grade levels will be a combination of skills, learning dispositions, and standards. Skills and habits of mind such as the 21st Century Skills of Creativity, Critical Thinking, Collaboration and Communication will be woven and infused into learning activities along with PA STEELS Standards and Practices, and Next Generation Science Standards.

Learning Outcomes

1. Students will develop an understanding of the engineering design process.
2. Students will develop the ability to apply the engineering design process.
3. Students will develop perseverance through trial and error and experimentation.
4. Students will develop an understanding of and be able to apply the 21st Century Skills of creativity, critical thinking, collaboration and communication.
5. Students will develop an understanding of and be able to use online communication platforms.

PA STEELS Standards

1. 3.2.2.A Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties
2. 3.2.2.B Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose
3. 3.2.2.D Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot
4. 3.5.K-2.K- Safely use tools to complete tasks
5. 3.5.K-2.M- Demonstrate essential skills of the engineering design process
6. 3.5.K-2.N- Analyze how things work
7. 3.5.K-2.O- Illustrate that there are different solutions to a design and that none are perfect
8. 3.5.K-2.Q- Apply skills necessary for making in design
9. 3.5.K-2.S- Apply design concepts, principles, and processes through play and exploration
10. 3.5.K-2.V- Explain that materials are selected for use because they possess desirable properties and characteristics
11. 3.5.K-2.DD- Collaborate effectively as a member of a team
12. 3.5.K-2.CC- Discuss the roles of scientists, engineers, technologists, and others who work with technology

Transfer.	
Students will be able to independently use their learning to … ● Persevere through challenging problems while demonstrating a Growth Mindset. ● Demonstrate adaptability in order to apply Design Thinking to solve problems. ● Utilize the engineering design process for a variety of problems. ● Conduct tests/experiments to analyze structures and materials. ● Approach problems with curiosity and creativity. ● Compare, contrast and evaluate possible solutions for problems by thinking critically. ● Collaborate with others in various roles. ● Utilize written and spoken communication methods in order to explain thinking, planning, and problem solving processes. ● Ask questions to clarify their understanding of a concept. ● Create models for a variety of purposes.	
Meaning	
Enduring Understandings	**Essential Questions**
Students will understand that... ● The engineering design process begins with imagination and planning before creating. ● Building materials can vary in many ways and these factors may determine the effectiveness of a material. Ex. Strength, Durability, Buoyancy. ● Shapes and structural choices play a role in building. ● Models can be utilized to solve problems and as means of demonstration. ● Communication and collaboration are critical for success.	*Students will keep considering….* ● How do engineers use the design process to solve problems? ● What can team members do to help the group or team? ● How do materials and shapes affect a project? ● How can building a model help solve a problem? ● How can I communicate my thinking and ideas?

Acquisition	
Acquisition of Knowledge	Acquisition of Skills
Students will know... ● The engineering design process can be used to solve problems and involves using creativity and planning to create solutions. ● Properties of materials affect the success of a building project and must be considered prior to building. ● Creativity, critical thinking, collaboration and communication are essential to engineering success.	*Students will be skilled at....* ● Using a variety of materials and techniques to create models or structures. ● Using age appropriate tools safely and correctly. ● Perform roles that contribute to the success of a team. ● Communicate through a variety of methods including creating an online portfolio of work samples and artifacts.

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<tr><th colspan="2">Stage 2 –Evidence</th></tr>
<tr><td colspan="2">Performance Tasks</td></tr>
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Icebreaker activities and challenges
Bridge building with a variety of materials
Marble Runs with Marble Genius
House building for strength of materials
DIY Playdough
Paper Airplane Design
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<tr><td>Other Evidence</td><td>Student Self-Assessment</td></tr>
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Observation
Online Portfolio Artifacts
Photos of design stages, including final product
Videos (products and reflections)

Peer Reviews
Pre-Flight Checklists
2 Stars and a Wish

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Individual and team reflection videos
Self Assessment Rubric
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Stage 3 –Learning Plan
Sequence and Description of Performance Tasks and Design Challenges

Collaboration and Partner Practice Activities- Can be used as icebreakers and set the foundation for collaboration in the STEM Classroom (2 Class Sessions)
● Cup Stacking
    ○ Day 1 will be a variety of challenges for students building with cups. Challenges can include building differing shapes and structures, using 1 hand, different sizes of cups, and other constraints.
    ○ Day 2 will require students to create a tool to move cups. Students will not be allowed to touch cups.
 	
Bridge Construction (2-3 Class Sessions)
● A variety of materials will be used and tested tas students work in teams to build bridges that can hold weight.
    ○ The Three Billy Goats Gruff will be read to begin the challenge.
    ○ Students will plan and create bridges with a variety of materials and building principals.
    ○ The students will test the bridges to hold the "3 billy goats."
    ○ Students will build with Legos (staggering bricks for strength), craft sticks (stronger when placed on edge), and index cards (creating columns and triangular supports).
    ○ Portfolio posts will be targeted to students demonstration of understanding of engineering design process as well as demonstration of an understanding of differences in materials and shapes within structures.
 	
Marble Runs with Marble Genius Sets and App (2 Class Sessions)
● Collaborative project completing challenges on Marble Genius app
    ○ Students will plan and create marble runs to meet constraints of time and materials.
    ○ Basic principles of gravity and friction will be discussed and implemented by students.
    ○ Evidence of learning will include self and peer assessments targeting collaboration.
 	
DIY Playdough (4 Class Sessions)
● Students will work with a variety of materials in different states of matter and observe their interactions to create a recipe for playdough.
    ○ Students will work with solids and liquids and combine them under a set of circumstances that may affect solubility.
    ○ Students will determine the attributes of high quality playdough.
    ○ Students will design a process that produces high quality playdough.
    ○ Pre-flight checklists can be used during the design process and 2 Stars and a Wish at the conclusion.

Paper Airplane Design (4 Class Sessions)

- Students will develop and use an understanding of forces necessary for flight as well as some fundamentals of aircraft design to create paper airplanes.
    - Students will follow procedures to create hoop gliders and twirly copters to develop understanding of lift and gravity.
    - Students will learn and apply basics of design including symmetry and balance to create paper airplanes and test them for a distance flight.
    - Students will follow procedures and plans to create airplanes.
    - Students will design their own airplane.

Additional Challenges and Activities

- Free STEM Classes
    - Students will be able to work with a variety of building materials or STEM tools. Choices may include: Lego, Cup Towers, Block, Box Forts, Contraption Labs, Design and Draw.
- Holiday or Special Activities
    - Halloween- Build With Bones (Marshmallows and toothpicks)
    - Thanksgiving- Balloons over Broadway
    - Christmas- Rocket Sleigh
    - St. Patrick's Day- Leprechaun Trap

Subject	STEM	Grade Level	3
Title of Unit	Engineering	Time Frame	15 Class Meetings
Stage 1 - Desired Results			
Established Goals & Learning Outcomes The desired results for the STEM Engineering Units in all grade levels will be a combination of skills, learning dispositions, and standards. Skills and habits of mind such as the 21st Century Skills of Creativity, Critical Thinking, Collaboration and Communication will be woven and infused into learning activities along with PA STEELS Standards and Practices, and Next Generation Science Standards.			

Learning Outcomes

1. Students will develop an understanding of the engineering design process.
2. Students will develop the ability to apply the engineering design process.
3. Students will develop perseverance through trial and error and experimentation.
4. Students will develop an understanding of and be able to apply the 21st Century Skills of creativity, critical thinking, collaboration and communication.
5. Students will develop an understanding of and be able to use online communication platforms.

PA STEELS Standards

1. 3.2.3.A Make and communicate observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion
2. 3.2.3.B Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object
3. 3.3.3.A Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
4. 3.3.3.C Make a claim supported by evidence about the merit of a design solution that reduces the impacts of a weather-related hazard
5. 3.5.3-5.C Follow directions to complete a technological task
6. 3.5.3-5.I Design solutions by safely using tools, materials, and skills
7. 3.5.3-5.K Judge technologies to determine the best one to use to complete a given task or meet a need
8. 3.5.3-5.M Demonstrate essential skills of the engineering design process
9. 3.5.3-5.N Identify why a product or system is not working properly
10. 3.5.3-5.O Describe requirements of designing or making a product or system
11. 3.5.3-5.P Evaluate the strengths and weaknesses of existing design solutions, including their own solutions

12. 3.5.3-5.Q Practice successful design skills.
13. 3.5.3-5.S Illustrate that there are multiple approaches to design.
14. 3.5.3-5.T Apply universal principles and elements of design.
15. 3.5.3-5.Z Create a new product that improves someone's life.
16. 3.5.3-5.AA Create representations of the tools people made, how they cultivated to provide food, made clothing, and built shelters to protect themselves.
17. 3.5.3-5.HH Differentiate between the role of scientists, engineers, technologists, and others in creating and maintaining technological systems.

Transfer
Students will be able to independently use their learning to ... ● Persevere through challenging problems while demonstrating a growth mindset ● Demonstrate adaptability in order to apply Design Thinking to solve problems ● Utilize the engineering design process for a variety of problems ● Conduct tests/experiments to analyze structures and materials ● Approach problems with curiosity and creativity ● Compare, contrast and evaluate possible solutions for problems by thinking critically ● Collaborate with others in various roles ● Utilize written and spoken communication methods in order to explain thinking, planning, and problem solving processes ● Ask questions to clarify their understanding of a concept ● Create models for a variety of purposes

Meaning	
Enduring Understandings	**Essential Questions**
Students will understand that... ● The engineering design process is a fluid plan that does not necessarily need to be completed in order; to create effective solutions cycling back and forth through steps may be necessary. ● Engineers create and manipulate forces and energy for multiple purposes. ● Multiple designs may address and be appropriate to solve the same problems or situations. ● Engineers often work with or depend on the work of others in STEM fields. ● Models can be utilized to solve problems and as means of demonstration. ● Communication and collaboration are critical for success.	*Students will keep considering….* ● What do engineers do other than build and create? ● How can the engineering design process be used to create life improving technology? ● How can math and scientific concepts be applied to design thinking? ● How can I communicate my thinking and ideas? ● What can I do to ensure quality collaboration among a team?

Acquisition	
Acquisition of knowledge	Acquisition of skills
Students will know... ● The engineering design process can be used to solve problems and involves using creativity and planning to create solutions. ● Engineers not only design structures, but also manipulate energy, forces, and other natural phenomena. ● Creativity, critical thinking, collaboration and communication are essential to engineering success.	*Students will be skilled at....* ● Using a variety of materials and techniques to create models or structures. ● Using age appropriate tools safely and correctly. ● Perform roles that contribute to the success of a team. ● Communicate through a variety of methods including creating an online portfolio of work samples and artifacts.

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Icebreaker Activities and Challenges
Pool Noodle Roller Coasters
Wind Proof Towers
Catapult Construction

</td></tr>
<tr><td>Other Evidence</td><td>Student Self-Assessment</td></tr>
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Observation
Online Portfolio Artifacts

Photos of design stages, including final product
Videos (products and reflections)

Peer Reviews

Pre-Flight Checklists
2 Stars and a Wish

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Individual and Team reflection videos
Self Assessment Rubric
Pre-Flight Checklists
2 Stars and a Wish

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Stage 3 –Learning Plan

Sequence and Description of Performance Tasks and Design Challenges

Collaboration and Partner Practice Activities- Can be used as icebreakers and set the foundation for collaboration in the STEM Classroom (2-4 Class Sessions)

- Cups, Cubes, and Craft Sticks Design Challenge
    - Students will be given an assortment of items that all vary in shape. They will be challenged to use them to create a series of structures.
    - Each structure will be built to meet a set of constraints (one cube base, one cup base as examples).
- Indi Robot Tracks
    - Students will use the Indi robot and complete challenge cards.
    - Students will design original "tracks" for Indi to drive (use each color once, use every tile, create circuit tracks).

Pool Noodle Roller Coasters (2-3 Class Sessions)

- Students will work in teams to create marble track "roller coasters" using pool noodles.
    - Teams will need to complete slow motion videos of their roller coasters in action.
    - Teams can work on a series of challenges including loops and jumps in their track.
    - Furniture, tape, cups, and other supports can be offered as aids to students.

Windy City Towers (2-3 Class Sessions)

- Teams will work to create paper skyscrapers that can withstand windy conditions.
    - Students will be given 4 sheets of paper, tape and weights.
    - Fans will be used to create wind and test strength.
    - Students will design the parameters for the testing.

Catapult Construction (5 Class Sessions)

- Students will work both collaboratively and independently to design and build craft stick and binder clip catapults.
    - Students take this completed project home.
    - Students will first complete Newton's Second Law Egg Drop Challenge to bring terms such as force and potential and kinetic energy into discussion.
    - Students will build and test "Old School Catapults" to discover tension and torsion as ways to create energy/force.
    - Students will implement all phases of the engineering design process to design, build and communicate the progress and results of their projects.

- Pre-flight Checklists, 2 Stars and a Wish along with drawn designs will all be submitted in a thoughtful online portfolio post.

Additional Challenges and Activities

- Free STEM Classes
  - Students will be able to work with a variety of building materials or STEM tools. Choices may include: Lego, Cup Towers, Block, Snap Circuits, Coding Robots or activities, Design and Draw, and other various activities.
- Holiday or Special Activities
  - Halloween- Build With Bones (Marshmallows and toothpicks)
  - Thanksgiving- Balloons over Broadway
  - Christmas- Rocket Sleigh
  - St. Patrick’s Day- Leprechaun Trap

Subject	STEM	Grade Level	4
Title of Unit	Engineering	Time Frame	15 Class Meetings
Stage 1 - Desired Results			

Established Goals & Learning Outcomes
The desired results for the STEM Engineering Units in all grade levels will be a combination of skills, learning dispositions, and standards. Skills and habits of mind such as the 21st Century Skills of Creativity, Critical Thinking, Collaboration and Communication will be woven and infused into learning activities along with PA STEELS Standards and Practices, and Next Generation Science Standards.

Learning Outcomes

1. Students will develop an understanding of the engineering design process.
2. Students will develop the ability to apply the engineering design process.
3. Students will develop perseverance through trial and error and experimentation.
4. Students will develop an understanding of and be able to apply the 21st Century Skills of creativity, critical thinking, collaboration and communication.
5. Students will develop an understanding of and be able to use online communication platforms.

PA STEELS Standards

1. 3.2.4.B Make and communicate observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents
2. 3.3.4.B Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation
3. 3.5.3-5.C Follow directions to complete a technological task
4. 3.5.3-5.I Design solutions by safely using tools, materials, and skills
5. 3.5.3-5.K Judge technologies to determine the best one to use to complete a given task or meet a need
6. 3.5.3-5.M Demonstrate essential skills of the engineering design process
7. 3.5.3-5.N Identify why a product or system is not working properly
8. 3.5.3-5.O Describe requirements of designing or making a product or system
9. 3.5.3-5.P Evaluate the strengths and weaknesses of existing design solutions, including their own solutions
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11. 3.5.3-5.S Illustrate that there are multiple approaches to design

12. 3.5.3-5.T Apply universal principles and elements of design
13. 3.5.3-5.Z Create a new product that improves someone's life
14. 3.5.3-5.AA Create representations of the tools people made, how they cultivated to provide food, made clothing, and built shelters to protect themselves
15. 3.5.3-5.HH Differentiate between the role of scientists, engineers, technologists, and others in creating and maintaining technological systems

Transfer What kinds of long term independent accomplishments are desired? *Students will be able to independently use their learning to…..*
Students will be able to independently use their learning to ... • Persevere through challenging problems while demonstrating a Growth Mindset • Demonstrate adaptability in order to apply Design Thinking to solve problems • Utilize the engineering design process for a variety of problems • Conduct tests/experiments to analyze structures and materials • Approach problems with curiosity and creativity • Compare, contrast and evaluate possible solutions for problems by thinking critically • Collaborate with others in various roles • Utilize written and spoken communication methods in order to explain thinking, planning, and problem solving processes • Ask questions to clarify their understanding of a concept • Create models for a variety of purposes

Meaning	
Enduring Understandings	**Essential Questions**
Students will understand that... ● The engineering design process is a fluid plan that does not necessarily need to be completed in order; to create effective solutions cycling back and forth through steps may be necessary. ● Engineers create and manipulate forces and energy for multiple purposes ● Multiple designs may address and be appropriate to solve the same problems or situations ● Engineers often work with or depend on the work of others in STEM fields ● Models can be utilized to solve problems and as means of demonstration ● Communication and collaboration are critical for success	*Students will keep considering….* ● What do engineers do other than build and create? ● How can the engineering design process be used to create life improving technology? ● How can math and scientific concepts be applied to design thinking? ● How can I communicate my thinking and ideas? ● What can I do to ensure quality collaboration among a team?

Acquisition	
Acquisition of Knowledge	Acquisition of Skills
Students will know... ● The engineering design process can be used to solve problems and involves using creativity and planning to create solutions. ● Engineers not only design structures, but also manipulate energy, forces, and other natural phenomena. ● Creativity, critical thinking, collaboration and communication are essential to engineering success.	*Students will be skilled at....* ● Using a variety of materials and techniques to create models or structures. ● Using age appropriate tools safely and correctly. ● Perform roles that contribute to the success of a team. ● Communicate through a variety of methods including creating an online portfolio of work samples and artifacts.

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Recycled Materials Marble Run
Snap Circuits
Makey Makey Instruments
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Stage 3 –Learning Plan
Sequence and Description of Performance Tasks and Design Challenges

Collaboration and Partner Practice Activities- Can be used as icebreakers and set the foundation for collaboration in the STEM Classroom (2-4 Class Sessions)

- Beach Erosion Challenge (2 Class Sessions)
    - Teams will work to design and create solutions to beach erosion.
    - First class session will be used to demonstrate the effects of erosion using a "beach" created in a plastic bin and opportunity for students to brainstorm and design.
    - Second class session will be an opportunity to create their own model with some type of erosion protection built into their "beach."
- Bridge Building Challenge and Testing (2 Class Sessions)
    - Students will work in teams to design, build and test craft stick bridges.
    - Multi-page portfolio posts will be created by students.

Recycled Materials Marble Run (2-3 Class Sessions)

- Collaborative project for students to build a marble run with cardboard and other recycled material
    - Students will use Contraption Lab and Marble Genius runs to discover means of friction and slope to control marble speed.
    - Constraints will include the area that is covered by the run and the elapsed time of the run.
    - Students will design an original run and then be challenged to add a set amount of time to the run.

Snap Circuits (1 Class Session)

- Students will work in teams to complete a snap circuit project.
    - Projects must contain a switch of some kind to complete or alter the circuit.
    - Circuit experience will be utilized in the Makey Makey project.

Makey Makey Instruments (4-5 Class Sessions)

- Students will work to create working musical instruments using recycled materials and a Makey Makey to produce sound.
    - Students will learn the basics of wiring their Makey Makey to a paper piano.
    - Students will create a logical video game controller to match a game.
    - Students will work in partner groups to build instruments and complete a recording of a song for their online portfolio.
    - Students will complete Pre-flight Checklists and 2 Stars and a Wish to document in their portfolios.

Solar Oven (3-4 Class Session)

- Students will work in teams to design and create solar ovens.
    - Students will design, test and possibly use solar ovens to bake cookies.
    - Students measure initial temperature and find ways to improve upon their design.
    - Data collection and experimental methods will be a focus of the project in addition to energy transfer.

Additional Challenges and Activities

- Free STEM Classes
    - Students will be able to work with a variety of building materials or STEM tools. Choices may include: Lego, Cup Towers, Block, Snap Circuits, Coding Robots or activities, Design and Draw, and other various activities.
- Holiday or Special Activities
    - Halloween- Build With Bones (Marshmallows and toothpicks)
    - Thanksgiving- Balloons over Broadway
    - Christmas- Rocket Sleigh
    - St. Patrick's Day- Leprechaun Trap

Subject	STEM	Grade Level	5
Title of Unit	Engineering	Time Frame	15 Class Meetings
Stage 1 - Desired Results			
Established Goals & Learning Outcomes The desired results for the STEM Engineering Units in all grade levels will be a combination of skills, learning dispositions, and standards. Skills and habits of mind such as the 21st Century Skills of Creativity, Critical Thinking, Collaboration and Communication will be woven and infused into learning activities along with PA STEELS Standards and Practices, and Next Generation Science Standards.			

Learning Outcomes

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2. Students will develop the ability to apply the engineering design process.
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4. Students will develop an understanding of and be able to apply the 21st Century Skills of creativity, critical thinking, collaboration and communication.
5. Students will develop an understanding of and be able to use online communication platforms.

PA STEELS Standards

1. 3.1.3.G Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.
2. 3.2.5.F Support an argument that the gravitational force exerted by Earth on objects is directed down
3. 3.3.5.F Generate and design possible solutions to a current environmental issue, threat, or concern
4. 3.5.3-5.C Follow directions to complete a technological task
5. 3.5.3-5.I design solutions by safely using tools, materials, and skills
6. 3.5.3-5.K Judge technologies to determine the best one to use to complete a given task or meet a need
7. 3.5.3-5.M Demonstrate essential skills of the engineering design process
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16. 3.5.3-5.HH Differentiate between the role of scientists, engineers, technologists, and others in creating and maintaining technological systems

Transfer What kinds of long term independent accomplishments are desired? *Students will be able to independently use their learning to…..*
Students will be able to independently use their learning to … ● Persevere through challenging problems while demonstrating a Growth Mindset. ● Demonstrate adaptability in order to apply Design Thinking to solve problems ● Utilize the engineering design process for a variety of problems ● Conduct tests/experiments to analyze structures and materials ● Approach problems with curiosity and creativity ● Compare, contrast and evaluate possible solutions for problems by thinking critically ● Collaborate with others in various roles ● Utilize written and spoken communication methods in order to explain thinking, planning, and problem solving processes ● Ask questions to clarify their understanding of a concept ● Create models for a variety of purposes

Meaning	
Enduring Understandings	**Essential Questions**
Students will understand that… ● The engineering design process is a fluid plan that does not necessarily need to be completed in order; to create effective solutions cycling back and forth through steps may be necessary. ● Engineers create and manipulate forces and energy for multiple purposes. ● Multiple designs may address and be appropriate to solve the same problems or situations. ● Engineers often work with or depend on the work of others in STEM fields. ● Models can be utilized to solve problems and as means of demonstration. ● Communication and collaboration are critical for success.	*Students will keep considering….* ● What do engineers do other than build and create? ● How can the engineering design process be used to create life improving technology? ● How can math and scientific concepts be applied to design thinking? ● How can I communicate my thinking and ideas? ● What can I do to ensure quality collaboration among a team?

Acquisition	
Acquisition of Knowledge	Acquisition of Skills
Students will know... ● The engineering design process can be used to solve problems and involves using creativity and planning to create solutions. ● Engineers not only design structures, but also manipulate energy, forces, and other natural phenomena. ● Creativity, critical thinking, collaboration and communication are essential to engineering success.	*Students will be skilled at....* ● Using a variety of materials and techniques to create models or structures. ● Using age appropriate tools safely and correctly. ● Perform roles that contribute to the success of a team. ● Communicate through a variety of methods including creating an online portfolio of work samples and artifacts.

<table>
<tr><th colspan="2">Stage 2 –Evidence</th></tr>
<tr><td colspan="2">Performance Task</td></tr>
<tr><td colspan="2">● Icebreaker Activities and Challenges
● Miniature Golf Course
● Biome in a Box Green Screen Movies
● Student Choice of STEM Projects</td></tr>
<tr><td>Other Evidence</td><td>Student Self-Assessment</td></tr>
<tr><td>● Observation
● Online Portfolio Artifacts
○ Photos of design stages, including final product
○ Videos (products and reflections)
● Peer Reviews
○ Pre-Flight Checklists
○ 2 Stars and a Wish</td><td>● Individual and Team reflection videos
● Self Assessment Rubric
● Pre-Flight Checklists
● 2 Stars and a Wish</td></tr>
</table>

<table>
<tr><th>Stage 3 –Learning Plan</th></tr>
<tr><td>Sequence and Description of Performance Tasks and Design Challenges</td></tr>
<tr><td>Collaboration and Partner Practice Activities- Can be used as icebreakers and set the foundation for collaboration in the STEM Classroom (2 Class Sessions)
● 10 Apples Up on Top Challenge
○ Revisiting the challenge from Unit 1, students will work in teams to create some type of hat that can hold apples on top of a student’s head.
○ The first class session will be used to work through Ask, Imagine, and Plan stages of EDP.
○ The second class session will be used to Create, Improve and Communicate.</td></tr>
</table>

Miniature Golf Course (3 Class Sessions)

- Students work in teams to create minigolf holes. Ideally, there will be nine teams in the class to create a nine hole golf course.
    - The first class session will be a planning session. Teams will be required to collaborate amongst themselves and with other teams to ensure originality in the golf course. Teams must work so that each hole is unique.
    - The second class session is an opportunity for students to build and improve upon their design based on the feedback from other teams.
    - The final class is an opportunity for students to play the golf course and complete online posts that include a "commercial" for their class golf course.

Biome in a Box Green Screen Movies (5 Class Sessions)

- This project will be a continuation of a project begun in 5th grade science class. Students will be paired in their science class and create a biome in a shoebox and fact sheet that illustrate and detail examples of animal and plant life in a particular region of the world. In STEM, they will utilize the Green Screen App to create videos of themselves "inside" their shoebox.
    - Students will initially learn to use the Green Screen App and complete green screen "tricks" by producing a "rolling ball video" where they show a rolling ball traveling through a variety of places.
    - Students will then create storyboards to plan their films.
    - Students will film their projects in the green screen studio.
    - Students will complete their projects by editing their films in the app and posting to their online portfolio.

Student Choice Projects (5 Class Sessions)

- Students will be tasked with improving on the results from at least one project they have completed in previous STEM Engineering Units. Once the one project has been revisited and improved, students will have the opportunity to choose a new project to complete.
    - Choices may include (but are not limited to): kindergarten boats, 1st grade robots, second grade paper airplanes, 3rd grade catapults, 4th grade Makey Makey instruments.
    - Students will be required to post to their online portfolios throughout the project, beginning with why they chose the project and taking viewers through their planned improvements and the finished product.
    - Students who are new to the school and STEM program will be given choices from these same projects to create for the first time.
    - Once a project has been completed, students may choose from any of the materials in the STEM room to continue creating their own choice projects .

Appendix A
Curriculum Resources

Unit	Resource Description
1	Read Aloud Texts ● Ten Apples Up on Top by Dr. Suess ● Curious George Visits the Zoo by Margret Rey ● Curious George and the Boat Show by Kate O'Sullivan ● The Three Little Pigs by Paul Galdon
2	Read Aloud Texts ● The Three Billy Goats Gruff by Janet Stevens ● Canstruction Creations by Cameron Morais Video Clips ● Honda - The Cog ● World Record Paper Airplane Flight - John Collins
3	Read Aloud Texts ● Iggy Peck, Architect by Andrea Beaty Video Clips ● Behind the Chunk - Catapults
4	Video Clips ● Solar Oven - NatGeoTV ● OK Go - This Too Shall Pass
5	Apps ● Green Screen by DoInk Websites ● TinkerCAD

*All units and grade levels will utilize the Seesaw App as an online portfolio

Appendix B
Examples of Assessment Forms and Data Collection Sheets

Catapult Testing: Data Collection Sheet

Record the distance and accuracy of 10 catapult shots then discuss the questions as a team. Write down your answers and be prepared to discuss your ideas!!

Attempt #	Distance (cm)	Accurate (Y or N)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

What worked well on your catapult?

List 2 problems you had when launching your catapult. How do you think you could fix these problems?

Contraption Lab Learning Log

Group Names:

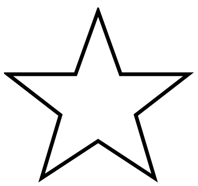
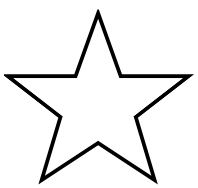
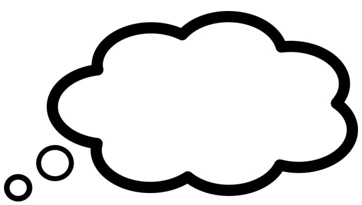
Description of Piece	Describe the Function of this Piece

Be Prepared to discuss how each piece can change the speed of your marble!!!

2 Stars and a Wish

Group Names:

Directions: Examine all pages of your Seesaw Post. Choose 2 things that you believe made your creation work well and 1 thing that you wish could have been improved!

Pre-Flight Checklist

Directions: Help another team make sure their Makey Makey instrument is ready for Seesaw! Check the boxes and let them know what you think!

Does the instrument have enough keys to play all of the needed notes for their song?	YES	NO
Will the instrument be able to be wired to the Makey Makey board? Make sure the wires will be long enough to reach keys	YES	NO
Is there space on the instrument for the Makey Makey board and will the alligator clips fit?	YES	NO
Is the instrument able to be connected to Earth and constantly grounded throughout the song?	YES	NO

Do you have any comments or suggestions for this instrument or video?

____

____

Green Screen Story Board

Sketch	Script	Green Screen Effect

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William J. Laughlin Jr.

Profile

Educator focused on engaging students with meaningful learning opportunities to prepare students to become productive citizens of the global community in the 21st Century.

Professional Experience

K-5 STEM Teacher – Alloway Creek Elementary School (2018-Present)

- Plan and facilitate weekly STEM activities and challenges for students in grades kindergarten through five with the purpose of improving students' 21st Century Skills
- Utilize various websites, apps, and hardware to create and implement coding program for students in kindergarten through fifth grade
- Create educational opportunities for students to understand and implement design thinking with a focus on the Engineering Design Process
- Collaborate with teacher leadership and administration to adopt PA STEELS Standards for science instruction
- Work in tandem with the Alloway Creek Art Department to design and direct annual STEAM Night program for all families and stakeholders of the Littlestown Area School District

Classroom Teacher – Sandymount Elementary (2009-2018)

- Plan, both collaboratively and independently, and present engaging instruction for all elementary school subjects
- Partner with other Carroll County school teachers and supervisors to write and pilot new STEM curriculum aligned to Next Generation Science Standards
- Collaborate with teachers and supervisors to embed Discovery Education assets within existing Carroll County lessons
- Serve on school leadership team for Discovery Education rollout, providing professional development to all grade levels
- Wrote and received a grant from Northrop Grumman in the field of STEM Education
- Work in partnership with school administration and financial secretary to identify and meet goals in regards to educational technology within school building

Education

McDaniel College

- Elementary STEM Instructional Leadership Program Certificate

McDaniel College

- Bachelor of Arts – English, Elementary Educator Minor (December, 2008)
- Kappa Delta Pi (International Education Honor Society) – inducted 2008
- ETS Excellence Award Recipient – 2009