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Redesigning and Expanding WPI's Summer STEM Programs for Middle School Girls

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Redesigning and Expanding WPI's Summer STEM Programs for Middle School Girls

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Abstract

The underrepresentation of females in STEM fields limits innovation. The purpose of this project was to develop resources for the Office of Pre-Collegiate Outreach Programs at Worcester Polytechnic Institute to aid them in their expansion of summer STEM programs, increasing opportunities for middle school girls to get involved as well as increasing female engagement in STEM. We analyzed the effectiveness of previous activities and developed 25 modules as frameworks for designing effective STEM outreach programs for 6th, 7th, and 8th grade girls.

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Executive Summary

The underrepresentation of females in STEM fields limits innovation. The purpose of this project was to develop resources for the Office of Pre-Collegiate Outreach Programs (POP) at Worcester Polytechnic Institute (WPI) to aid them in their expansion of summer STEM programs, increasing opportunities for middle school girls to get involved as well as increasing female engagement in STEM. This is necessary because formal schooling often lacks the elements needed to engage girls with STEM, including eliminating social biases, providing strong female role models, and properly developing girls' existing talent. Our research focused mainly on middle school pedagogy, best practices for STEM teaching for girls, the benefits of informal education, standard curriculum in Massachusetts schools, and more to understand what standards a girls' STEM outreach programs should have. We analyzed the effectiveness of previous activities at WPI and developed 25 modules from our research as frameworks for designing effective STEM outreach programs for 6th, 7th, and 8th grade girls.

One of the middle school summer STEM programs that the Office of POP sponsors is Camp Reach. They established this program in 1997 and has since run it annually. It is open to rising 7th grade girls, who stay at WPI for the duration of the two-week program. It also utilizes activities that engage girls and exposes them to problem solving using the engineering process. However, they currently must turn many girls away due to capacity issues. The POP Office wants to increase the number of opportunities available to include more middle school girls by expanding the current program to include all three grade levels of middle school.

Project goals and Methodology:

The goal of our project was to design STEM activity guidelines for a set of summer programs, which include rising 6th, 7th, and 8th grade girls. Additionally, we aimed to expand the number of STEM fields included in the current program, identify successful activities in the past Camp Reach program, and develop content for academic knowledge covered in each grade level. These contributions will aid the Office of Pre-Collegiate Outreach Programs in developing activities and schedules for the expanded program, which includes 60 more participants than the previous Camp Reach Program. In order to achieve this goal, we developed the following research objectives:

1. **Assess the needs of the Pre-Collegiate Outreach Programs Office:** We had set out to learn the type of deliverables that would be the most beneficial to the Office of POP, as they will be the main consumers of our recommendation. We interviewed the director of the Office of POP to understand their desired specifications better for the deliverables.
2. **Identify successful workshops in the current Camp Reach Program:** We decided to analyze past Camp Reach survey results to gain insight about past activities in the program. The POP Office provided us with survey data from 2008 through 2018. We

analyzed the quantitative ratings for all the activities to discover which activities were successful and or needed improvement.

3. **Develop modules for middle school programming:** We utilized an iterative process to formulate our content. Our final iteration of the module structure included the following subsets: STEM field of interest, problems and themes with social relevance, age appropriate content and learning objectives, and sample activities.

    a. **Identify STEM fields of interest:** We utilized our interview with the Director of the POP Office as well as analysis of past Camp Reach Schedules to study which fields have been included in the program in the past, as well as those that were not included but the Office of POP wished to include in the future set of programs. Additionally, we referred to the literature to determine which STEM fields had the lowest female involvement. We contended that the STEM fields with the lowest female involvement were critical to the program, as these fields will need more female representation.

    b. **Identify socially relevant problems that the STEM fields of interest help conquer:** We utilized the TeachEngineering website and WPI publications to brainstorm socially relevant issues that STEM professionals address.

    c. Determine age appropriate content and learning objectives: We utilized the Massachusetts Department of Elementary and Secondary Education's Curriculum (DESE) to determine what adolescents are learning in their formal school environment. Our goal was to provide them with activities that would introduce them to content they will be learning about in the next year, as well as build off the content they studied in the previous year. We also decided that it was essential to formulate learning objectives for each activity in order to show exactly what it is the girls should retain from their experience at Camp Reach. We used outside of school time programming best practices to formulate the learning objectives.

    d. Generate sample activities for the STEM fields of interest: We utilized our experiences, WPI faculty pages, past Camp Reach activities, and educational websites to generate sample activities for the series of programs.

Outcomes and Recommendations:

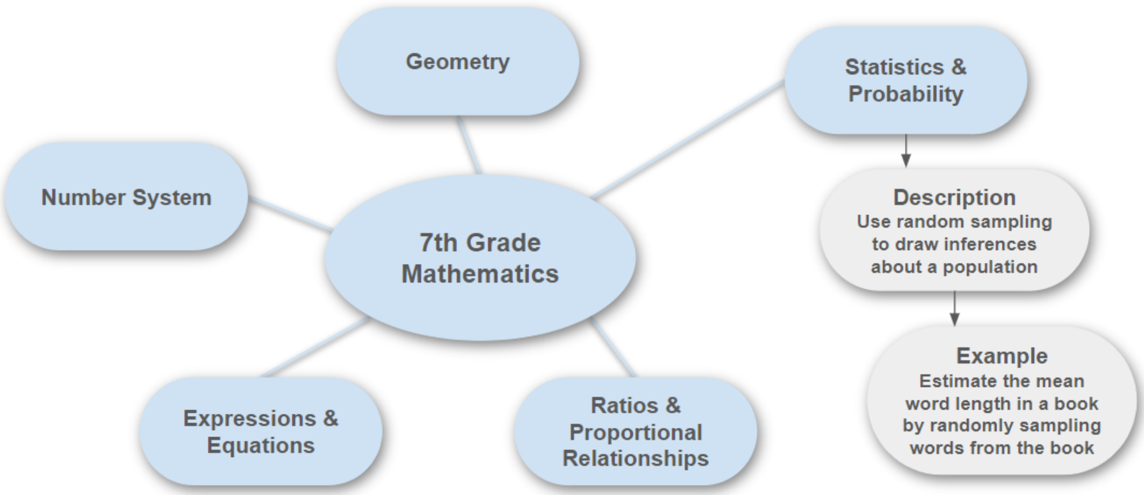
When we considered possible sample activities to include in our recommendation, we looked at past Camp Reach activities. This developed into a deliverable for the Office of POP that included SMART ratings for previous Camp Reach activities (see Table 1).

Table 1: Past Camp Reach Activity Ratings

Activity Title	SMART Rating	Activity Title	SMART Rating
Chem Eng (2016)	4.7	NASA Rocket (2011)	3.5
Boston Museum of Science (2018)	4.5	Who Dunnit (2010)	3.5
Chem Eng: Bath Fizzies (2017)	4.2	Sustainable Energy (2008)	3.4
Assistive Art Device (2018)	4.1	Rehab Engineering (2014)	3.4
Roller Coasters (2018)	4.1	Sandcastles (2010)	3.4
Bio Med: Device for Ear (2014)	3.9	Salt Marsh (2009)	3.4
Rocket Launching (2017)	3.9	Bio Med: ECG (2011)	3.4
Solidworks (2018)	3.9	Snack Attack (2009)	3.3
Ice Cream Sundae: Tech Comms (2015)	3.8	Chem Eng: Glo Germs (2011)	3.3
Industrial Eng: Mr. Potato Head (2016)	3.8	Bio Medical (2010)	3.2
Forensics (2009)	3.8	Chem Eng: Microscopy (2011)	3.2
Wacky Shoes (2016)	3.8	Civil Eng: Wind Power (2008)	3.2
Robotics (2013)	3.8	Rehab DDR (2015)	3.1
Bose (2016)	3.7	Camp Reach Magazine (2010)	3.0
EE Dance Pad Mania (2018)	3.7	Personal Safety Training (2010)	2.9
Environmental Detectives (2016)	3.6	Budget Savvy (2010)	2.9
Bio Med (2016)	3.6	Sunscreen (2009)	2.6
Google SketchUp (2017)	3.5	Math U (2009)	2.6
Unbirthday Design (2016)	3.5	Chem Eng: Beam Counting (2011)	2.4

From the DESE standards, we summarized all the content in the categories of mathematics and science, technology, and engineering for 5th, 6th, 7th, and 8th grade. Figure 1 shows a simplified example of our deliverable. This example summarizes the content covered in the 7th Grade Math curriculum, specifically for the topic of statistics and probability.

Figure 1: Simplified 7th Grade Math curriculum



We also developed a set of 25 modules for the POP Office to use when developing activities for future Camp Reach programs. Each module consists of seven subsets. Table 2 explains what information would be in a module. Each section contains an explanation of the content that the reader can find there.

The resources created for the Office of POP enables them to develop an extended set of programs more easily, thus allowing more girls to attend and get involved in STEM. The framework developed includes three programs rather than one, increases the capacity from 30 to 90 girls, and includes 25 workshops rather than 10. Additionally, we included three more STEM fields that were not covered in the previous program. Increasing participation and potentially maintaining interest is a step toward solving more of the world's greater problems by further diversifying STEM fields.

Table 2: Module structure

STEM Field	This refers to what field students would learn about or discover using the following ideas in the module.
Social Relevance	This subset shows the real-world problem that engineers in the given field might have to solve. It is a very important piece in the utilization of the module, as it both lays the groundwork for an activity and gives middle school girls the drive they need to learn about engineering by making a connection to helping others. We highly recommend the POP Office keep this subset as it is or very similar when creating activities.
Academic Knowledge	Massachusetts Department of Elementary and Secondary Education (DESE) curriculum supplied all the information in this subset. It is the knowledge all incoming students will have from formal education at Massachusetts public schools which relates to the learning objectives of the module. The POP Office should use this as background knowledge on the middle school students when modifying or creating activities to ensure that these do not introduce too much or too little unknown information.
Grade Level	This subset is our recommended grade level (for rising middle school students) for the given activity. The Office of POP should take this as only a suggestion as it comes from the related academic knowledge that students should have from formal schooling. Program creators may use this module effectively at other grade levels if they modify the activity to use other background knowledge.
Learning Objectives	These are the takeaways students should have about what engineers do, how they do it, and why it matters to the students and to the world. These are as important as the social relevance to the overall module, and we recommend keeping consistent themes in all the learning objectives of all the modules.
Sample Activity	This subset contains a sample of an activity that uses the information in the given module. The sample does not go in depth on the logistics of the program, but rather ensures that learning objectives are covered and that presenters are aware of the concepts they should communicate to the students. The Office of POP may use these sample activities in their programming as they are or modify them as necessary, but we again recommend that similar learning objectives are present for the sake of improving STEM interest.
Industry Connection	This final subset connects what students learned to do and what problem they learned to address with related actions one might see an engineer performing in their respective field. The POP Office should use this portion to inform campers who want to continue in this field about potential careers they may seek out.

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Chapter 1: Introduction

Collaborative, creative, and diverse thinkers can solve many critical global issues. These attributes – which most science, technology, engineering, and math (STEM) oriented individuals possess – are necessary to develop innovative ideas that can make the world a better place. In 2010, the President's Advisory Council on Science and Technology revealed that there is a need for individuals with competencies in science, math, technology, and engineering for the nation to be internationally competitive (PCAST, 2010). In order to provide the nation with more individuals that have a solid STEM foundation, there must be an increase in the number of women involved in these fields. Only 20% of students who graduate with an engineering degree are female, and this gender gap between men and women is not only present at the collegiate level; it begins during adolescence (Vincent-Ruz & Schunn, 2017).

Current research demonstrates three main theories about the existence of the gender gap: gendered socialization, peer groups, and stereotypes of professionals in the STEM field. This research reveals that existing societal stereotypes have a substantial impact on the way society socializes young females, which leads to a decline in engagement in STEM subjects (Reinking & Martin, 2018). Studies also reveal the influence that peer groups have on students during their most difficult adolescent years: middle school. The success of peers as well as the acceptance of classmates can easily affect children at this stage (Reinking & Martin, 2018). Therefore, it is essential that STEM programs portray STEM courses as positive experiences, and that activities relating to it are a popular pastime for children, so that they may influence each other in the correct direction. Additionally, the stereotype that people who have STEM careers are socially awkward and introverted tends to drive away females because they are naturally social and interactive beings (Reinking & Martin, 2018). If more females were to get a broader view of different professionals in the STEM field, then they would be more attracted to it.

There are several methods that are useful to engaging girls in STEM, such as eliminating bias, providing strong female role models, and properly engaging and developing girls' talent in STEM areas (Meadows, 2016). However, formal STEM education is lacking the ability to engage young girls, which increases the importance of more informal forms of education such as extracurricular activities or summer camps. Formal schooling tends to discourage children who are not high performers from STEM because there exists a stigma of it being for high performers only. Therefore, they are discouraged and have this idea ingrained within them that they cannot excel in math and science subjects (Stearns, E., Bottía, M. C., Davalos, E., Mickelson, R. A., Moller, S., & Valentino, L, 2016). Schools often disengage high performers from STEM subjects as well, because they tend to focus on the students that are at risk of failing, while not paying attention to the boredom and disinterest of the high performers. Therefore, STEM education outside the classroom is beneficial across all demographics. It engages the low performers by instilling confidence in their abilities as well as provides the challenge and real-world application that high performers are lacking in formal education.

One camp whose mission is to maximize engagement of young females in STEM is Worcester Polytechnic Institute's (WPI) Camp Reach. Camp Reach is a summer residential program at WPI that is currently open to 30 rising 7th grade girls. The program received a Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring from President Obama in 2011. The two-week program exposes girls to different engaging and fun STEM activities that demonstrate the various STEM fields available, with a focus on engineering. Research demonstrates that Camp Reach has had significant results. It has positively changed the perception that many young women have on engineering (Demetry and Sontgerath, 2013). However, they currently must turn many girls away due to capacity issues. As mentioned previously, middle school is a critical time in adolescent girls' lives because a myriad of factors may influence and socialize them. If the program is open to all three grades of middle school, students will encounter STEM throughout their entire middle school journey along with the support system of the role models and community that the camp provides.

The goal of our project was to design STEM activity guidelines for a set of summer programs, which include rising 6th, 7th, and 8th grade girls. Additionally, we aimed to expand the number of STEM fields included in the current program, identify successful activities in the past Camp Reach program, and develop content for academic knowledge covered in each grade level. These contributions will aid the Office of Pre-Collegiate Outreach Programs in developing activities and schedules for the expanded program, which includes 60 more participants than the previous Camp Reach Program. The increase in capacity will provide more opportunities for young females, as well as increase the number of innovative thinkers that are able to service the community and make the world a better place.

Chapter 2: Background

This chapter begins with an assessment of female representation in STEM fields and the surrounding issues. We then investigate the potential causes of the lack of diversity in order to understand how we should overcome said issues boundaries. We then discuss the notion of informal education and its features that formal education lacks, and we review engineering-based activities that appeal to girls specifically. This is for the sake of discovering the best methods to boost self-efficacy and confidence in STEM identity in middle school girls, with the hopes of understanding how to inspire STEM career choices. Finally, we examine the current structure of Camp Reach at Worcester Polytechnic Institute (WPI) and the educational benefits of sequential programming to expand on our knowledge about how best to provide resources for future programming.

2.1 Addressing the lack of female representation in STEM careers

According to the Economics and Statistics Administration, women occupied 47% of the jobs in the United States in 2017. However, women only occupied 24% of science, technology, engineering, and math careers. Additionally, even though women make up slightly more than half of the population with a college degree, they only hold 25% of STEM degrees. There is a clear disproportionality between men and women's involvement in STEM fields, as women are more likely to work in education or healthcare (ESA, 2017). This disparity expresses itself even more in certain subsets of STEM such as mechanical or computer engineering. Many of the STEM subsets listed in Table 3 have an alarmingly low percentage of women (NSF, Science and Engineering Indicators, 2016).

However, women in general tend to be more involved in fields that include personal interactions such as social science and psychology (National Science Foundation, 2015), causing a drastic disparity in other subsets of STEM. Eliminating this gender gap is essential to producing revolutionary solutions to the world's problems since diversity is key to problem solving and innovation. A group of people who can look at a problem from a multitude of perspectives is more apt at finding innovative solutions than a group of people who think the same way (Folk-Williams, 2010). In order to have more diverse groups of individuals collaborating to solve problems, more women must be involved in STEM fields — for without their engagement, many organizations will lack diversity, resulting in a lack of inventiveness. Additionally, STEM fields are growing rapidly with many job openings and opportunities in which women need to take part. STEM fields are a place for creative thinkers with ingenuity. There are many women who exhibit these characteristics, and STEM careers need them (Lyons, 2016). However, women are missing many opportunities that are only available to them in science and technology careers. STEM jobs are also lacking their intelligence and passion. Therefore, this gender disparity is harmful to not just women but to society.

Table 3: Percentage of women in the workforce in STEM fields (2016)

STEM Field	Percentage of Women in the Field
Mechanical Engineering	7.9%
Electrical/Computer Engineering	10.7%
Physics and Astronomy	11.1%
Industrial Engineering	17.1%
Civil/Architectural Engineering	17.5%
Chemical Engineering	22.7%
Environmental Engineering	33.8%
Chemistry	35.2%
Economy	37.5%
Social Science	59.8%
Psychology	72.8%

2.2 Theories regarding the disparity between male and female engagement in STEM

There are many theories behind the reasons for the gender gap, one of which is gendered socialization. Parents and society together socialize boys and girls differently. The methods that parents use to raise their children are key in determining the career paths that the children choose. The advice parents give, the materials they provide, and the experiences they offer their children can have a substantial influence on the choices they make about their future (Leaper, 2014). Parents have a significant impact on the development of a child's "self" or identity. To sociologists, identity development is a process that is continuously changing based on social interaction and culture (Gould & Lewis, 2018). There is also the theory of the "looking glass self" in which sociologist Charles Cooley explained identity development as a role-play process where children watch those around them to develop their own identity. They mimic their parents, cartoon characters, teachers, and others around them, and they start to interpret the world and form social realities through this role-play process (Gould & Lewis, 2018). Therefore, if these role models believe in gender stereotypes such as "math and science is for boys" or "girls are supposed to be caretakers", then that will be a social reality for the children who follow.

There are also stereotypes that women have subpar abilities in STEM subjects. This stereotype is communicated to young women subconsciously by their loved ones, and it can cause feelings of self-doubt and lack of confidence (Reinking & Martin, 2018). When a child lacks self-efficacy, an individual's belief in achieving goals, they also develop the mindset that they are limited in ability (Meadows, 2016). Research does not demonstrate that males pursue math at a higher rate than females because they are better at it, they do so because they believe that they have a talent in that area. People who believe that they can achieve their dreams and are aware of their potential are able to achieve their goals (Meadows, 2016). If young women had a better sense of self-efficacy, they would choose to pursue careers in STEM because they have more confidence in their abilities regardless of the cultural stereotypes.

Peer groups are also an essential theory for why girls are not engaged in STEM. Classmates have a substantial impact on each other during middle school years (Reinking & Martin, 2018). Support or rejection from peers can have a considerable influence on a child's school experience, influencing their academic achievements. If they perceive academic success as "cool", students will strive for it. If it is "uncool", they will avoid it to fit in. Research proves that peer support has a positive association with girls' engagement in STEM (Reinking & Martin, 2018). If peers are supportive of each other's academic success, they can motivate one another to pursue academics, including STEM subjects. Eventually academic success will become a social norm and academically successful girls will not have to fear alienation.

There are certain stereotypes about the typical STEM personality that drive girls away from the field. Isolation is a prominent stereotype that many people associate with computer scientists and engineers. However, society often raises women to be social beings and interactors (Reinking & Martin, 2018). This is a clash between how women see themselves in society and the stereotypical STEM personality. Stereotypes about the culture of math and science fields, the types of people working in them, their values, and the tasks they perform tend to steer females away from them. (Cheryan, Master, & Melzoff, 2015). Research shows that women who interacted with stereotypical computer science students were less interested in pursuing the major than those who interacted with non-stereotypical computer science students who were social and had different passions such as sports (Cheryan, Master, & Melzoff, 2015). Additionally, college women who observed scientists who spent their day isolated and performing independent tasks were less interested in that field than women who watched social scientists perform collaborative tasks (Cheryan, Master, & Melzoff, 2015). Therefore, changing this image of the isolated scientist to a more open, and social one will engage more women to join the wide variety of STEM career fields.

2.3 Benefits of supplementing formal education with informal education

Both formal and informal education have tremendous potential to enhance or suppress girls' interests in STEM. "Formal education" typically refers to learning that takes place in an institutional setting apart from everyday life, where educators use very systematic and verbal curriculum that "focuses on training as an end in itself" (Rogoff, Callanan, Gutiérrez, & Erickson, 2016). However, the definition of "informal education" has been vague among researchers in the past. Whatever setting one finds it, informal education usually includes a few key aspects. "It is non-didactic; is embedded in meaningful activity; builds on the learner's initiative, interest, or choice (rather than resulting from external demands or requirements); and does not involve assessment external to the activity" (Rogoff, et al., 2016). This encompasses educational after-school programs, summer camps, and even museums, as these all can include firsthand activities or group projects which themselves encourage learning, build upon and reward the participants' interest, and connect back to the real world, all without academic expectations and pressures.

The best informal settings are comfortable and accepting for a greater range of students because they are closer to everyday life and foster constant interaction. This supplies space for learners of any prior knowledge or ability to take part in STEM ideas and activities (Bell, et al., 2009). While a formal learning space rewards those of a more scientific background, the informal classroom allows students to draw from their own background when they tackle a problem, providing them with a better understanding of the information they are learning (Barton, Tan, & Rivet, 2008). A high-quality informal program would "prompt and support participants to interpret their learning experiences in light of relevant prior knowledge, experiences, and interests," (Bell, et al., 2009). For a simple example, a student who loves to sing would be more eager to engage with a topic if they can write a song about it rather than write flashcards describing it, as formal pedagogy would suggest (Barton, Tan, & Rivet, 2008). Rigorous curricula and constrictive methods prohibit students from approaching their work in a method more relatable to themselves as individuals, something that increases their personal interest in the material.

In addition to including all types of learners, informal pedagogy can influence the identities of learners, affecting how they study and what they value in their education. In a typical classroom situation, strict rules about how to conduct oneself and socialize with peers are enforced. In extracurricular learning spaces, however, socializing is encouraged, as it acts as an outlet for learning in which any student can comfortably participate. McCreedy and Dierking (2013) found specifically that having science-interested peers "with whom they identify is recognized as an important reason that some girls stay engaged in such programs." People form identities about themselves when they socialize with those around them, so befriending people who enjoy STEM will make their interest increase as well, something that is encouraged in the more social, informal setting. In an investigation of a summer Coastal Ecology program for girls in Virginia, Riedinger and Taylor (2016) were able to show that girls could author new identities in their group work that others recognized and accepted. Most young girls do not see themselves succeeding in or enjoying science or engineering, so this ability to have students take on new identities as people who practice STEM makes informal programs powerful. The acceptance of oneself from others in this group also serves to bolster one's self-efficacy with the subject. Middle school girls tend to shape their interests around being able to "fit in" with their friends, so when their friends recognize and validate their new STEM interests, they will continue to pursue it and feel confident in their decision. This shows that effective informal education has the potential to increase the interest of young females as well as increase their self-efficacy when it comes to success in STEM careers.

2.4 Effective STEM teaching for engaging girls

The main methods that are useful for engaging girls in STEM are introducing strong female role models, providing positive experiences, and developing girls' talent in STEM areas (Meadows, 2016). The bias and stereotypes that engineering is a male's field and that only anti-social introverted individuals are in those types of fields is one of the main reasons that girls are disengaged from it. Females are social and interactive beings; therefore, they see themselves more fitting for career paths that include a lot of social interaction. However, the media and overall culture engrains that stereotype of STEM fields in children's heads (Reinking et al., 2018). For this reason, having role models to illustrate a personalized version of what an engineer looks like, rather than the stereotypical image, will spark interest in young girls. Role models are an essential part of the engagement process because girls need other girls like them to whom they can aspire and with whom they may relate. Studies have shown that "Exposure to female role models who have succeeded in math has been shown to improve performance on math tests and to invalidate these stereotypes" (Halpern et al, 2007). Additionally, when girls perform higher with the support of their mentor, they can see the potential for their own growth. "Students with a growth mindset consistently try to stretch themselves beyond their comfort zone to learn new things" (Dweck, 2012). This growth mindset teaches girls to be adventurous and to try things they are not accustomed to, such as STEM. Studies have also shown that girls who attend schools with more female math and science teachers have higher chances of pursuing careers in STEM (Stearns et al, 2016).

Another essential aspect of the engagement process is providing positive experiences associated with STEM. Many children associate mundane tasks such as textbook reading and calculations to STEM activities. They do not see math and science courses as an opportunity for creativity and design. They also do not see the relevance of their course work or its application to the real world (Cooper and Heaverlo, 2013). Girls tend to focus on creativity and real-world applications. However, they do not see the connection between STEM and these characteristics. They view STEM career fields as task-oriented rather than people-oriented, and they believe procedure guides the tasks rather than creativity. In 2008, The National Academy of Engineering highlighted the importance of the need for design and problem solving in the STEM field. Research shows that girls who have a passion for problem solving are likely to be interested in science, technology, math, and science (Cooper and Heaverlo, 2013). Girls who indicated an interest in design are also likely to be interested in computers and engineering (Cooper and

Heaverlo, 2013). If girls had a better understanding of what a STEM experience constitutes and what passions they can apply in STEM subjects, then there would be a higher percentage of girls interested in working in STEM fields.

2.5 Dimensions of Success framework and its role in out of school time

An education research group at Harvard University developed a tool to assess the quality of informal science programs. They call the framework Dimensions of Success (DOS). It describes criteria that informal STEM programs should meet in order to provide a beneficial learning experience (Shah et al., 2017). DOS is a framework that consists of four domains each with three dimensions, all of which Table 4 demonstrates.

Observers of activities use this rating system to rate the quality of STEM programs quantitatively to demonstrate their compliance with the DOS standards, defined by the domains and dimensions (Shah et al., 2017). One of the informal science programs that utilizes this framework is Worcester Polytechnic Institute's (WPI's) Camp Reach.

2.6 STEM outreach programs for middle school girls at WPI

Currently, the Office of Pre-Collegiate Outreach Programs (POP) at WPI oversees four programs for middle school girls: Camp Reach, Women in Science, Girls Robotics, and Innovations in Biomedical Engineering. All of them vary in the targeted middle school age range, subject focus, and program structure. However, their main purpose is to promote interest in STEM fields to their participants. Focusing on Camp Reach, the POP Office has asked that we redesign the program into a series of 6^{th}, 7^{th}, and 8^{th} grade programs to increase the number of available spots.

Table 4: Dimensions of Success framework

Domains	Dimensions	Descriptions
Features of the Learning Environment	• Organization • Materials • Space Utilization	Materials are fun and correspond to learning goals. Learning environment is fitting for informal science teaching methods.
Activity Engagement	• Participation • Purposeful Activities • Engagement with STEM	All children have access so that they can participate. They see the connection between the activity and the learning goals. Facilitator uses their time efficiently. Students learn hands-on to make meanings without the answers being given.
STEM Knowledge and Practices	• STEM Content Learning • Inquiry • Reflection	The environment presents accurate and correct information with enough evidence to answer students' questions. Students can collect data, build models, and apply the knowledge they learned to perform engineering tasks. They reflect and build connections between what they are learning and their application in the real world.
Youth Development in STEM	• Relationships • Relevance • Youth Voice	Strong relationship between facilitator and the children. Facilitator encourages children's relationships with their peers. The facilitator connects the activities, the real world, and individual children's lives to show relevance in a broader context. Children have the opportunity to project their opinions and thoughts and be acknowledged by others.

2.6.1 Camp Reach

The POP Office established the Camp Reach program in 1997 and they have since run it annually. It is open to rising 7^{th} grade girls, who stay at WPI for the two-week duration of the program. It also utilizes activities that engage girls and exposes them to problem solving using the engineering process. Additionally, it also aims to sustain interest by continuing contact with the participants and their guardians through a Facebook group as well as reunions held at WPI (Demetry & Sontgerath, 2018). Five design principles create the foundation for the current design of Camp Reach (Demetry & Sontgerath, 2018).

1. Challenging and supporting girls with multiple engineering design experiences in order to increase their self-efficacy.
2. Utilizing a wide variety of female role models in STEM and peer support to increase self-efficacy and serve as social support.
3. Showing how engineering can provide solutions to humanistic and people-oriented values and goals in order to create the connection that STEM is not all technical and can connect to girls' typical interests.
4. Facilitating multiple touchpoints with the girls after their Camp Reach experience to sustain the connections about engineering made at the program.
5. Involving the parents in the program to increase and encourage parental support.

Participants of the program complete a project during the duration of the program that encompasses many of the engineering design principles in order to create a meaningful and enriching experience. Although the projects are different each year, the overall premise is to solve a problem for a non-profit organization in Worcester through engineering practices (Demetry & Sontgerath, 2018). This incorporates how engineering can provide a way to solve a humanistic need and allows the girls to contribute to a solution to a societal problem. They work in a group with nine other girls, a middle school teacher, and a few high school students to guide and support them throughout the process. They can form relationships with role models in the form of both mentors and older peers. Working in groups provides peer support because as a team they help and encourage each other to use their knowledge of STEM practices to contribute. The students give a written report and an oral presentation to the client at the end of the program. The client will then implement at least some parts of the designs that the girls have proposed. There have also been instances when the girls were able to help with the physical implementation of the project the following year thus creating a stronger correlation to how engineering can help the community and people in general (Demetry & Sontgerath, 2018).

A series of workshops focusing on different areas in STEM creates diverse exposure in a variety of fields. These workshops consist of one main activity relating to the intended field of study that the girls complete in small groups (Demetry & Sontgerath, 2018). The purpose of these workshops is to develop a connection between technical fields and helping people in a direct and hands-on manner. They also incorporate group work to gain peer support.

Camp Reach includes other important events to better foster and sustain STEM interest. Parents are given an informational session at the beginning and end of the program which provides them current statistics about women in STEM and why it's important to increase those numbers (Demetry & Sontgerath, 2018). They also receive information on the importance of their role in encouraging their own children to pursue STEM and supporting them along the way. Lastly, the parents themselves are encouraged to foster interest by giving their daughters more STEM enriching opportunities such as taking them to museums or allowing them to participate in other programs. After Camp Reach concludes, the POP Office continues to notify parents of a variety of STEM opportunities through a Facebook group. The purpose of this is to continue that needed parental support throughout middle school and high school. They also invite Camp Reach alumnae back to WPI for bi-annual reunions that incorporate social and STEM activities (Demetry & Sontgerath, 2016). The goal of these reunions is to continue interest by giving lasting support over time. Rising junior and seniors in high school who attended Camp Reach are also encouraged to apply to be teaching assistants and role models (Demetry & Sontgerath, 2018).

The follow-up results from the girls who attended Camp Reach shows the long-term effectiveness of summer programs in increasing girls' interest in STEM subjects. The Office of POP examined the Camp Reach applicants from 1997 to 2010 to see what type of college majors they pursued later in life. They split them into two groups: a) those who fully attended Camp Reach and b) those who they did not accept or did not fully complete the program. Girls who attended Camp Reach chose engineering majors at a rate of 15% compared to those in the control group who chose at a rate of only 9.1% (Demetry & Sontgerath, 2018). The rate at which the two groups chose general STEM fields showed no statistical difference with the Camp Reach group choosing at a rate of 35.4% and the control group choosing at a rate of 29.6% (Demetry & Sontgerath, 2018). Camp Reach focused heavily on engineering in the past, which has shown to influence their sustained interest in engineering later in life rather than just STEM fields. Another finding of the study showed that girls who continued to attend other aspects of Camp Reach, such as reunions, chose engineering majors more often. This shows that the sustained support that Camp Reach offers can maintain girls' interest in STEM throughout high school and the college decision-making process.

2.6.2 Other middle school programs at WPI

Women in Science is for 7th and 8th grade girls and runs during the day for five days. It introduces girls to STEM in the form of workshops and activities. WPI faculty, graduate students, as well as professionals in the industry lead the workshops to provide the girls with different kinds of role models with whom they could identify and learn. Each presenter guides the girls through an activity that highlights how STEM fields can be collaborative, creative, and solve humanistic issues.

Innovation in Biomedical Engineering is a one-week residential program open to 8th grade girls. Teams work in the labs at WPI on projects that are relevant to helping improve the well-being and health of people. Biomedical engineers guide these activities, which gives students role models in that field. Lastly, Girls Robotics is a five-day, day program for girls in 5th and 6th grade. It uses Lego Mindstorms robotics kits to promote interest in robotics engineering.

While these programs do reach a wider age range among middle school students, the POP Office did not create them to function together as a set. They rather created them in an opportunistic way as time went on. Our goal is to recommend a coherent set of activities that the

Office of POP can use for multiple grades, giving attendees a consistent and even more effective experience if they decide to return for multiple years.

2.6.3 Desire for expansion

The Office of POP requests the development of a series of 6th, 7th, and 8th grade summer programs to increase the number of opportunities available for middle school girls. Typical curriculum in schools is shaped around incremental challenge and building on prior knowledge. One topic in a class informs the next, and one entire course can lead into another. We frequently see sequences of courses in teaching systems even at the middle school level (e.g. one must take Algebra I before moving on to Algebra II, because the latter uses everything learned in the former). Existing research informs us that sequential learning, combined with proper spacing between study periods, increases students' retention of the material (Kang, 2016). In a study of this effect, referred to as the spacing effect, 8th graders split into groups that had study materials or review tests one week after learning them in class or 16 weeks after learning them. On the final exam nine months later, those who used the practice test scored much higher than their peers who only reread the study materials, and those who practiced after 16 weeks scored the highest overall, exemplifying their greater retention rate (Carpenter, 2009). In general, the greater the time between review sessions, the longer students retain the information.

Camp Reach at WPI already uses hands-on activities to teach and review its entire curriculum as opposed to reading and studying, accomplishing plenty for students in just one year. However, once the POP Office expands the camp to welcome students for multiple years in a series of programs, the amount of STEM education and career knowledge they can commit to memory and retain moving forward will increase. While this structure is advantageous for these reasons, students will still benefit from attending only one year. They are not required to return for each level.

In addition to the spacing effect, a multi-year program provides students with the time they need to form meaningful relationships with other classmates. Researchers have shown that "group membership" (being closely associated with groups of friends) and "group acceptance" (being appreciated by friends in the group) promotes academic performance. This is because of a resultant sense of belonging that inspires greater interest in the activities (Wentzel & Caldwell 1997). Addressing similar material year in and year out with plenty of campers attending for multiple years is bound to create a sense of group membership and acceptance within the middle school campers at Camp Reach. While the current program creates and fosters many friendships, the potential for this new program to have these relationships transcend years of middle school will strengthen them more and reap the educational benefits to a greater degree.

Camp Reach has been booked at max capacity every year. A creation building on the existing program will increase capacity and extend the opportunity to a wider range of students. Even 7th graders whom the POP Office would have denied because of previous space limitations and students who would have been unable to attend because of summer plans will have more opportunities to come to the camp in subsequent years.

Overall, a set of programs would encompass separate ones for 6^{th}, 7^{th}, and 8^{th} graders, which would help sustain support for STEM throughout middle school. In the past, Camp Reach has mainly focused on introducing engineering fields due to the limits on time. An expanded program would allow them to cover more topics in STEM more deeply, including computer science, physics, and game development.

Chapter 3: Methodology

The goal of our project was to design STEM activity guidelines for a set of summer programs, which include rising 6th, 7th, and 8th grade girls. Additionally, we aimed to expand the number of STEM fields included in the current program, identify successful activities in the past Camp Reach program, and develop content for academic knowledge covered in each grade level. These contributions will aid the Office of Pre-Collegiate Outreach Programs in developing activities and schedules for the expanded program, which includes 60 more participants than the previous Camp Reach Program. In order to achieve this goal, we developed the following research objectives:

1. Assess the needs of the Pre-Collegiate Outreach Programs Office
2. Identify successful workshops in the current Camp Reach Program
3. Develop modules for middle school programming
    a. Identify STEM fields of interest
    b. Identify socially relevant problems that the STEM fields of interest help conquer
    c. Determine age appropriate content and learning objectives
    d. Generate sample activities for the STEM fields of interest

In this chapter, we describe our methods to gather and analyze input from the POP Office and other sources to develop a recommendation for a STEM summer program for middle school girls.

3.1 Assess needs of the Pre-Collegiate Outreach Programs office

We set out to learn what type of deliverables would be the most beneficial to the Office of POP, as they will be the main consumers of our recommendation. We then interviewed the director of POP Office to understand their desired specifications for the deliverables better. We determined that an informal interview was the best method to solidify our knowledge about the purpose of our project and gain perspective about the key components that were essential to our deliverable. This type of interview was also the best method for us to be able to ask follow-up questions to clarify our understanding. The general topics areas of the interview included:

- Which type of activities should be included for each grade level?
- Which STEM fields should be included in the program?
- What is the ideal structure for the deliverable?

We used these interview topic areas and formulated questions to ask the director of the POP Office at WPI, Suzanne Sontgerath. We wanted to use her years of experience with Camp

Reach and other outreach programs at WPI to answer our research questions. We used the outcomes of this interview to develop a framework for "modules" as the key deliverable for this project, which guided the rest of our methodology.

3.2 Identify successful workshops in current Camp Reach program

We decided to analyze past Camp Reach survey results to gain insight about past activities in the program. The POP Office provided us with survey data from 2008 through 2018. This data included campers, teachings assistants, and middle school teachers' quantitative ratings and qualitative opinions on STEM, Camp Reach overall, as well as specific activities. We were interested in the quantitative ratings for the educational activities. For each activity, campers reviewed their enjoyment and learning. Teaching assistants and middle school teachers rated individual activities based on their opinion of how much the campers' learned from and enjoyed each activity. In order to condense this data into a single quantitative value for each activity, we found the average rating of enjoyment and learning from each of the three groups: the campers, TAs, and teachers.

A challenge that we faced was determining different weights for learning and enjoyment and determining which attribute was more significant for our recommendation. We overcame this challenge by referring to the literature. Research provides theories that adolescents retain more content in fun, and engaging informal environments (Barton, Tan, & Rivet, 2008). Therefore, we decided that the most significant factor in an activity is enjoyment, if an activity is enjoyable, then adolescents will learn the most.

Once we determined that enjoyment was more significant for our recommendation, we faced another obstacle. We needed to determine how much more significant enjoyment was than learning. We used a decision-making tool to determine appropriate weightings for the two attributes. The Simple Multi Attribute Rating Technique (SMART) aids in weighing and combining multiple ratings or factors (The Simple Multi Attribute Rating Technique, 2014). It provides statistically analyzed weights for factors and allows the user to select the most fitting of four methods. We chose the method that creates the largest range in final numbers since the original range of the data is small, which made it difficult to visually detect significant variations.

We calculated weighted averages for each of the campers', TAs', and middle school teachers' ratings. Then we used SMART to derive a single rating from the three groups' ratings for each activity. We retained some activities that scored above average in this final category as part of the recommendation.

3.3 Develop modules for middle school programming

During our weekly meetings, we received feedback from both our advisor and sponsor, and we modified the structure of our deliverable in accordance with their suggestions. We used an iterative process to develop the structure of the modules. Our final iteration of the module structure included these subsets: STEM field of interest, problems and themes with social relevance, age appropriate content and learning objectives, and sample activities.

3.3.1 Identify STEM fields of interest

The main purpose of Camp Reach is to engage more female adolescents in STEM for the underrepresentation of women in STEM fields to decrease. To comply with the program's purpose, we needed to determine which STEM fields were critical to the program.

We utilized our interview with the Director of the POP Office as well as analysis of past Camp Reach Schedules to study which fields have been included in the program in the past, as well as those that were not included but the Office of POP wished to include in the future set of programs.

Additionally, we referred to the literature to determine which STEM fields had the lowest female involvement. We contended that the STEM fields with the lowest female involvement were critical to the program, as these fields have the most desperate need for more female representation. We used the National Science Foundation Statistics to obtain the data on female representation in various STEM fields in the workforce.

3.3.2 Identify problems and themes with social relevance

One of our design principles was to design activities that have a humanistic connection as part of our recommendation. Studies show that females regard STEM fields more highly when they are exposed to the connection between STEM and the real world (Cooper & Heaverlo, 2013). If they see the application of STEM in helping solve societal issues, girls will be more likely to pursue engineering careers. Therefore, we needed to identify societal problems that engineers aim to solve daily.
To brainstorm problems for a given STEM field, we utilized two resources:

1. TryEngineering.org
2. WPI publications about faculty and student research at the university

TryEngineering is a resource whose aim is stimulate interest in students for different engineering fields and provide students with information on how and why they should get involved in these fields, as well as the educational knowledge required for each field. We utilized this tool to learn more about the engineering fields that we chose to include in our recommendation. We used it to identify the societal impact that the different types of engineers have as well as the key societal issues they address in their careers.

We examined publications for research done by WPI professors related to our chosen STEM fields. We utilized these publications for inspiration for activities related to science, technology, and math. We analyzed the social relevance of their research and used it for inspiration when we were developing activities for the program.

3.3.3 Determine age appropriate content and learning objectives

One of our key objectives was to have age appropriate content for each grade level so that students do not get discouraged, but instead improve their self-efficacy when participating in the program. Studies reveal that one of the root causes for the gender gap in STEM is females having lower self-efficacy regarding STEM topics. If women had higher self-efficacy and adopted a growth mindset, more young women would be open minded to pursuing STEM (Meadows, 2016). Some questions that had arisen during this process of identifying age appropriate content were:

- Which STEM topics are appropriate for 6^{th}, 7^{th}, and 8^{th} grade participants?
- How can we ensure that the activities are challenging without being too complex?

To address these questions, we utilized the Massachusetts Department of Elementary and Secondary Education's Curriculum (DESE) to determine what adolescents are learning in their formal school environment. Our goal was to provide them with activities that would introduce them to content they will be learning about in the next year, as well as build off the content they studied in the previous year.

We summarized key competencies that the students develop by the end of each grade level, as well as topics covered, a description of those topics, and examples that provide more detail. We put these summaries into the form of a table for each STEM subset and each grade level from five to eight. We then used the tables to determine whether activities were age appropriate or needed adjustment to be more fitting for the desired grade level. The tables that summarized the academic content were a tool that we used to ensure that the activities we designed were compatible with the adolescents' academic experiences.

We decided that it was essential to formulate learning objectives for each activity in order to demonstrate what the girls should retain from their experience at Camp Reach. An important aspect of Camp Reach's success is its ability to help sustain interest in the girls that attend the program. Girls who attend the program are statistically more likely to pursue engineering fields than girls who do not attend the program (Demetry & Sontgerath, 2016). We believe this success relates to what the campers are taking away after their camp experience. Learning objectives are a good way to provide students with a purpose for their learning experience, they guide instructors in forming instructional activities, and they direct assessment strategies ("Assessment and Instructional Alignment", n.d.) The POP Office also articulated the need for learning objectives in the recommendation as this is a missing aspect in their current program and it would be useful to planners and facilitators of the activities.

3.3.4 Generate sample activities

The final component of the module is a sample activity that the Office of POP can further develop into a workshop for the programs. Research shows that girls are more likely to be interested in STEM if they have positive experiences in their memory that they can relate to STEM. Therefore, we developed a process to generate engaging and creative sample activities that can foster an enjoyable STEM experience.

We completed the process of generating potential activities by looking at four main sources.

1. Personal Experience
2. WPI Faculty Pages
3. Past Camp Reach Activities
4. Educational Websites

Using our own individual knowledge, that we have gained through WPI curriculum as well as general past education, we utilized some activities that we have completed in the past for inspiration. We modified them to be more age appropriate for middle school girls as well as connected them to a real-world problem in order to create the necessary context and relevance to engage girls.

We researched WPI faculty pages as sources of inspiration because of their distinctive and specific STEM relating areas of research. The first step was looking at faculty who were involved in humanistic research topics. After we determined the humanistic connection behind their research and their STEM field, we assessed whether their research was age appropriate or too complex for middle school students using our knowledge of DESE standards. When the research was adjustable for middle school students, we were able to use the research as inspiration for a sample activity.

We used past Camp Reach activities that we identified as highly successful workshops with our analysis methods to generate sample activities. If those activities were relevant to the societal issues that we had identified, then we used them as part of our recommendation.

We also utilized online educational websites in our search. The most beneficial website was teachengineering.org, which follows Next Generation Science Standards as a basis for the content on their website. This website provided us with generic or basic activities for a variety of different engineering fields. This useful tool helped us form a basic activity for STEM fields with which we did not have much familiarity. Once we had a basis for learning objectives, we elaborated on the activities from this website and used our own creativity to develop the sample activities further.

Chapter 4: Outcomes

In this chapter, we present and analyze our findings during the research portion of our project to provide the Office of Pre-Collegiate Outreach Programs (POP) with resources for expanding their STEM summer programs for middle school girls in an effective way. The chapter begins with the specifications that the Office of POP gave for the deliverables, which guided the development of the modules. It then presents the ratings of past Camp Reach activities. The last section focuses on the content of a module.

4.1 Specifications from the office Pre-Collegiate Outreach Programs

From our interview with the director of the Office of POP, Suzanne Sontgerath, we obtained detailed information about what the POP Office would find most useful to develop the different summer programs for middle school girls (S. Sontgerath, personal communication, November 5, 2018).

Flexibility with program elements: When asked about a potential lack of long-term projects for the 6th and 7th grade programs, Ms. Sontgerath responded that it was not necessary due to the limited amount of time for those programs. The Office of the POP did not need a specific type of activity, whether a hands-on workshop or a project that spans multiple days. However, lest we limit any ideas, we concluded that if we found a more extensive project, we could include it in our recommendation.

Assumptions about presenters' knowledge: When creating the activities in our recommendation, Ms. Sontgerath explained that there should be a baseline understanding that a middle school teacher might potentially present them. This established who might deliver and explain the workshop to the girls, meaning that any more advanced topics that required specific technical knowledge may not always be possible. Our recommendation outlines an ideal scenario that the POP Office can adjust based on the resources and staff available.

Gaps in STEM field coverage: Ms. Sontgerath informed us that the main gap in STEM field coverage that Camp Reach has experienced is a lack of more advanced computer work. Therefore, we included computer science topics in our recommendation. Industrial and civil engineering were also some fields to focus on because girls tend to gravitate toward those fields. The Office of POP has not always had success in finding activities that are both unique and not already completed in formal schooling multiple times for these fields as well as other STEM fields in general.

Usefulness of Deliverable: The most helpful aspects, that Ms. Sontgerath identified about the outlined module, were the following the STEM field; social relevance, academic context, recommended grade level, and learning objectives. The STEM field establishes the focus of what the girls would be learning. Social relevance can give girls a more personal connection to the problems that the field focuses on and this will in turn make them more connected to the material. The academic context contains what the students have learned and will learn in formal schooling that relates to the activity, creating a connection to their own classes. Lastly, the learning objectives connect the previous four sections together and make generating a complete workshop from this module easier.

4.2 Highly rated Camp Reach activities

Utilizing the SMART rating system described in the previous chapter, we generated a table of all the educational activities implemented in Camp Reach since 2008. Table 5 shows the score for each activity as well as a color spectrum to indicate their score visually. The most recent year that the activity was completed is also included in the chart in order to differentiate activities that may have similar names. While analyzing the data from past Camp Reach, we found that activities that scored high in the fun category also scored highly in the educational category. This is consistent with our background research indicating that students often learn more when they are relaxed and enjoying what they are doing.

It is important to note that the lower rating activities could still potentially be improved and implemented successfully. One of the causes for a low rating could be a topic to which the girls could not relate, so the presenters would need to make the humanistic connection clearer and more relevant. Another possible fault could be inappropriate pedagogy. The girls may have spent too much time listening and watching rather than doing more engaging and hands-on learning. Lastly, the content within that activity might have been too difficult or easy and needs adjustment to be more age appropriate. The Office of POP should use the information presented in these ratings to see which activities need improvement and which ones would make good examples of a successful workshops.

4.3 Resources for developing future programs

For each recommended activity, we supply accompanying information that aids the Office of POP in scheduling and changing that activity. We displayed each activity in a format called a module. One module consists of a) the STEM field to which the activity relates, b) relevant social issues, c) required or suggested academic knowledge, d) suitable grade level(s), e) learning objectives, f) activity description, and g) connection to the industry. Each of these categories is a subset of its module.

4.3.1 STEM fields of interest

When we determined the STEM fields, we utilized the data from the NSF website regarding the percentage of women that are involved in these careers in the workforce to determine which fields had the lowest percentage of women (see Figure 2). We also looked at the Camp Reach Schedule data to discover which fields the program covered in the past and which were not included. Using these factors, we developed a synthesized list of STEM fields for our recommendation to the Office of POP (see Table 6).

Table 5: Ratings of Camp Reach's past activities

Activity Title	**SMART Rating**	**Activity Title**	**SMART Rating**
Chem Eng (2016)	4.7	NASA Rocket (2011)	3.5
Boston Museum of Science (2018)	4.5	Who Dunnit (2010)	3.5
Chem Eng: Bath Fizzies (2017)	4.2	Sustainable Energy (2008)	3.4
Assistive Art Device (2018)	4.1	Rehab Engineering (2014)	3.4
Roller Coasters (2018)	4.1	Sandcastles (2010)	3.4
Bio Med: Device for Ear (2014)	3.9	Salt Marsh (2009)	3.4
Rocket Launching (2017)	3.9	Bio Med: ECG (2011)	3.4
Solidworks (2018)	3.9	Snack Attack (2009)	3.3
Ice Cream Sundae: Tech Comms (2015)	3.8	Chem Eng: Glo Germs (2011)	3.3
Industrial Eng: Mr. Potato Head (2016)	3.8	Bio Medical (2010)	3.2
Forensics (2009)	3.8	Chem Eng: Microscopy (2011)	3.2
Wacky Shoes (2016)	3.8	Civil Eng: Wind Power (2008)	3.2
Robotics (2013)	3.8	Rehab DDR (2015)	3.1
Bose (2016)	3.7	Camp Reach Magazine (2010)	3.0
EE Dance Pad Mania (2018)	3.7	Personal Safety Training (2010)	2.9
Environmental Detectives (2016)	3.6	Budget Savvy (2010)	2.9
Bio Med (2016)	3.6	Sunscreen (2009)	2.6
Google SketchUp (2017)	3.5	Math U (2009)	2.6
Unbirthday Design (2016)	3.5	Chem Eng: Beam Counting (2011)	2.4

Figure 2: Percentage of working women in STEM

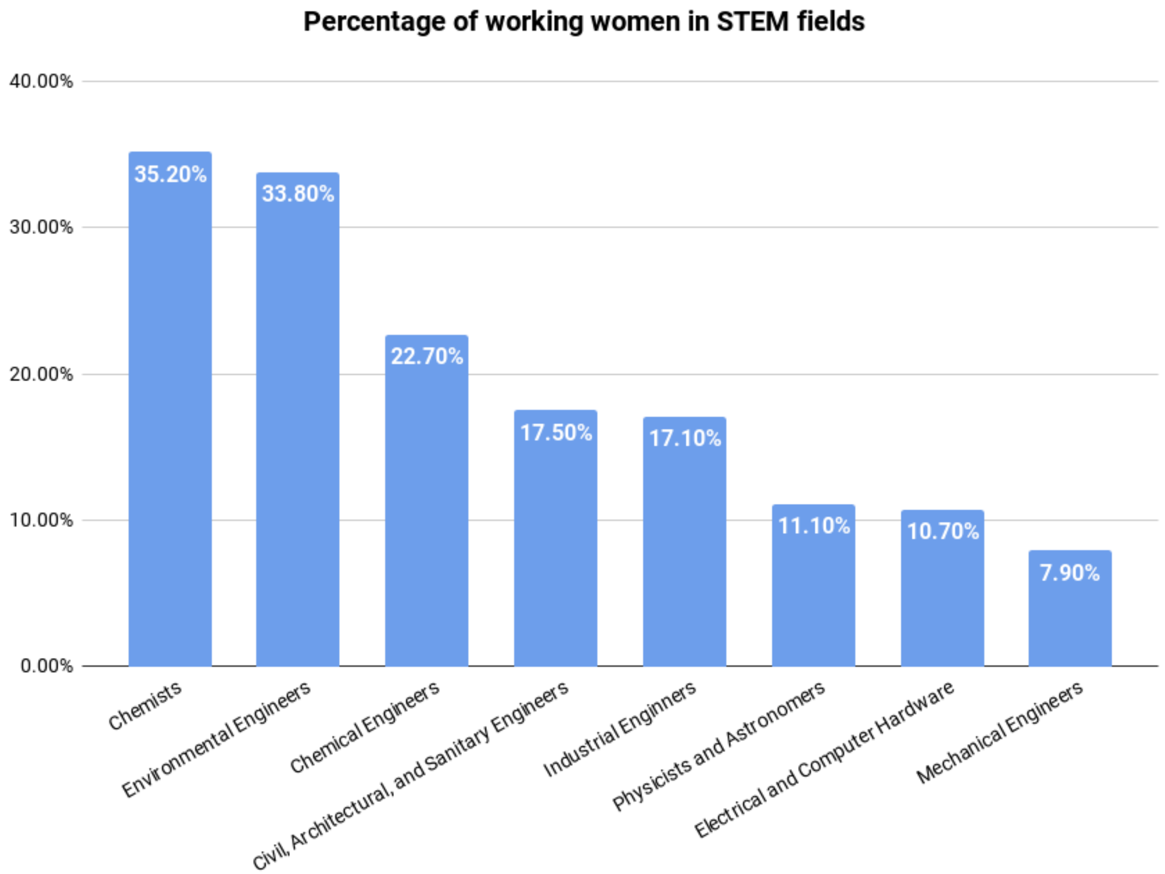

Table 6: STEM fields included in Camp Reach

Camp Reach STEM Fields	
Biology	Civil Engineering
Biomedical Engineering	Environmental Engineering
Mechanical Engineering	Chemical Engineering
Electrical Engineering	Math
Materials Engineering	Physics
Robotic Engineering	Computer Science
Industrial Engineering	Game Development

Key
Past field, not in recommendation
New field, in recommendation

4.3.2 Relevant societal issues

Workers in our selected STEM fields are always solving problems for people around the world. The next piece of our modules for the Office of POP includes these societal issues. As we learned in our literature review, an activity that tackles a problem relevant to the livelihoods of real people is more effective than activities that do not establish this connection. This type of activity especially affects girls in STEM, because women often aim to address more humanistic problems in their careers. Table 7 shows an example of these problems we discovered for each STEM field. To explain the reasoning behind our selection of relevant problems, we will give examples from the fields of computer science, game development, biomedical engineering, and industrial engineering.

The computer science and game development fields are becoming more and more integrated with the average person's life. New technologies and solving computing problems therefore held an immediate humanistic connection when we examined the field. In addition to this, the average young person has some familiarity with digital games. Serious games that address issues or educate players on them through their story and design are impactful to players. They usually aim to make the world a better place with their subject matter, and deliver an experience directly to people, making it a worthwhile topic for Camp Reach.

The Office of POP has included Biomedical Engineering as a field in the program for a long time and for good reason. Most issues addressed by workers in the field deal directly or indirectly with helping others' health. Engineers in this field design medical equipment and do research in life sciences and treatment. These issues are important to students because they contain a simple humanistic connection. Therefore, they would make highly effective activities.

A perfect example of why we identified the relevant issues we did in our STEM fields was those for industrial engineering. This is a field where engineers may not interact with subjects face-to-face, but still consider the lives and minds of people in most of their work. We included issues such as how to evaluate job performance, pay workers, and coordinate employee activities because they all deal with managing real people and providing them with a better environment to work in.

4.3.3 Middle school curriculum

Massachusetts Department of Elementary and Secondary Education's website provided us with raw data on information covered in each grade level from K-12. We used their resources to summarize the information covered in grades 5-8. We organized data into concise charts so that the Office of POP would be able to understand the gist of the subjects covered as well as examples of what the students are studying. Table 8 below is an example of the chart we developed for 6th grade math:

Table 7: Relevant problems in selected STEM fields

Field	Problems / Purpose
Computer Science	• Designing methods of keeping sensitive data safe. • Creating simulations and animations of real life for research and for entertainment
Game Development	• Entertaining and educating players through only artwork and storytelling. • Designing virtual worlds with the depth to act as a mental escape for players facing hardship in real life.
Civil Engineering	• Designing and supervising the construction of: roads, buildings, airports, tunnels, dams, bridges, water supply, and sewage treatment systems. • Designing artistic structures with more limited resources. • Ensuring the safety of people using these structures. • Developing structures that can resist harsh weather and natural disasters to protect people where they are prone to occur.
Mechanical Engineering	• Developing machines for people to work alongside in factories. • Creating physical prosthetics for people that mirror human anatomy and materials. • Making everyday machines that are safe for people to use.
Industrial Engineering	• Decrease wait time to improve quality of life • Designing production planning and control systems to coordinate activities, ensure product quality, and decrease price for consumers.
Electrical Engineering	• Generating electrical power and developing electronic devices that we use every day. • Creating assistive electronic devices for people with disabilities. • Designing secure wireless communications to ensure everyone can connect with one another for their safety and security.
Biomed Engineering	• Designing methods for administering drugs safely and to treat patients correctly. • Develop prosthetics or other assistive equipment to aid people with disabilities • Creating solutions to help injured patients heal quickly and safely. (casts, bandages, antibiotics, etc.)
Chemistry / Chemical Engineering	• Solving problems that involve the production or use of chemicals, fuel, drugs, food, and more to keep consumers safe. • Creating chemicals like home cleaning products for everyday use. • Developing renewable energy methods to save people money, meet the power needs of society, and prevent global warming.
Physics	• Ensuring that mechanical devices are safe to use (cars, heavy machinery, etc.) • Utilizing electrical principles to create everyday devices like speakers, screens, etc.
Robotics Engineering	• Designing prosthetics or accessibility devices for people with motor disabilities. • Using robotic equipment to keep human workers a safe distance from dangerous assembly lines.

Table 8: 6th Grade Math curriculum

Topic	**Description**	**Example**
Ratios and Proportional Relationships	A. Understand ratio and rate concepts and use ratio reasoning to solve problems. B. Use ratio language to describe a ratio relationship between two quantities. C. Understand the concept of a unit rate *a*/*b* associated with a ratio *a*:*b* with *b* ¹ 0, D. Use ratio and rate reasoning to solve real-world and mathematical problems	For example: This recipe has a ratio of three cups of flour to four cups of sugar, so there is ¾ cup of flour for each cup of sugar; We paid $75 for 15 hamburgers, which is a rate of five dollars per hamburger.
The Number System	A. Apply and extend previous understandings of multiplication and division to divide fractions by fractions. B. Compute fluently with multi-digit numbers and find common factors and multiples. C. Apply and extend previous understandings of numbers to the system of rational numbers. Understand where numbers lie on a number line as well as understanding the ordering and absolute value of rational numbers.	How many ¾-cup servings are in ⅔ of a cup of yogurt? For example, interpret –3 > –7 as a statement that –3 is located to the right of –7 on a number line oriented from left to right.
Expressions and Equations	A. Apply and extend previous understandings of arithmetic to algebraic expressions. B. Apply the properties of operations to generate equivalent expressions. C. Identify when two expressions are equivalent D. Reason about and solve one-variable equations and inequalities. E. Represent and analyze quantitative relationships between dependent and independent variables.	For example, in a problem involving motion at constant speed, list and graph ordered pairs of distances and times, and write the equation $d = 65t$ to represent the relationship between distance and time.
Geometry	Solve real-world and mathematical problems involving area, surface area, and volume. A. Find the area of right triangles, other triangles, special quadrilaterals, and polygons by composing into rectangles or decomposing into triangles and other shapes	

	B. Find the volume of a right rectangular prism with fractional edge lengths by packing it with unit cubes of the appropriate unit fraction edge lengths C. Draw polygons in the coordinate plane given coordinates for the vertices; use coordinates to find the length of a side joining points with the same first coordinate or the same second coordinate	
Statistics and Probability	Develop understanding of statistical variability. 1. Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers. 2. Understand that a set of data collected to answer a statistical question has a distribution, which can be described by its center (median, mean, and/or mode), spread (range, interquartile range), and overall shape. 3. Recognize that a measure of center for a numerical data set summarizes all its values with a single number, while a measure of variation describes how its values vary with a single number. Summarize and describe distributions. 1. Display numerical data in plots on a number line, including dot plots, histograms, and box plots.	For example, "How old am I?" is not a statistical question, but "How old are the students in my school?" is a statistical question because one anticipates variability in students' ages.

The first column is the topics covered in 6th grade math, the description is an explanation of what the students should understand about that topic, and finally the examples give insight about what problems the students are solving using their understanding of this topic. Program creators should use this chart when developing a 6th grade or 7th grade activity. When used to develop a 6th grade activity, they may refer to this chart along with the 5th grade chart to gauge the students' knowledge and see what they know and what they will learn next year. Using this information, they can engage in an activity that utilizes their former knowledge as well as introduces them to new concepts they will be learning so that they have a head start. Appendix B includes all of the curriculum summary tables for math as well as science, technology, and engineering topics covered from grades 5-8.

4.3.4 Workshop learning objectives

From our conversations with the Office of POP as well as our background research, we determined that the following are the most important objectives for our activity recommendation:

1. The students will draw connections between a specified STEM field and societal problem
2. The students will apply academic knowledge in an activity for a specified STEM field
3. The students will have the opportunity to participate in research, data gathering, and design practices that STEM professionals utilize

We personalized the three core learning objectives mentioned above with the context of each module to draw a connection between the modules and learning objectives.

4.3.5 Potential sample activities

This subset of our modules takes our all-important learning objectives and shows how program creators should integrate them into an activity featured as a part of Camp Reach. These sample activities show how and why to use our ideal learning objectives to create an effective program, rather than focusing on the staffing and logistical concerns of the full activities' implementations. In Table 9, we examine an activity from a mechanical engineering module we created as an example.

This sample activity uses plenty of hands-on actions to communicate learning objectives to students. This is because interactive activities are more engaging and easier to recall afterwards. In addition, since the students must work with the materials and construct the gripper themselves, they see firsthand the top three learning objectives in the module above and walk away from the program knowing them.

The end of the activity sees students using their grippers to interact with objects the way engineers in the field would use the same type of actuator. The presenter then must explain to the students this relation to the real world. This gives students the humanistic connection they need to stoke their interest in mechanical engineering, completing the final learning objective for the module.

Table 9: Example Mechanical Engineering activity (soft Robotics)

Learning Objectives	Students will be able to create a silicone mold. Students will examine why silicone is an ideal choice for soft robots. Students will be able to create an actuating gripper out of only soft parts. Students will recognize the role of a mechanical engineer in designing soft joints like the gripper to keep workers safe.
Sample Activity	Silicone Gripper: Students begin by making a mold for a cross-shaped gripper out of cardboard. Explain why silicone is the ideal material for this workshop (it's soft, cheap, easy to make a mold for, and most importantly flexible). They then fill the mold partially with uncured silicone and let it cure. Then, using a cross-shaped piece of acetate that will define the pneumatic channel, they fill the rest of the mold with uncured silicone around the acetate piece. A piece of fabric is added to the very top before the silicone cures so that it all freezes together. This produces a gripper with a hollow core, and the fabric prevents the fingers from bending in the wrong direction. By attaching a syringe of fluid that connects the channel inside the gripper, the students can actuate the gripper by inflating the silicone. From here the finished soft grippers can be used in a crane game, moving objects using only the gripper. Explain the connection to the matching real-world functions, in which a mechanical engineer would use similar materials to design soft joints like this to pick up pieces in an assembly line.

4.3.6 Aggregated Subsets

The combination of the above subsets creates an individual recommendation, which we call a "module". A module informs the Office of POP of a potentially effective activity and related details. Table 10 is an example of a module:

Table 10: Example module

STEM Field	Civil Engineering
Social Relevance	Weather conditions and natural disasters such as hurricanes and blizzards often damage or destroy homes.
Academic Knowledge	Technology and Engineering: Materials, Tools, and Processes: Present information that illustrates how a product can be created using basic processes in manufacturing systems, including forming, separating, conditioning, assembling, finishing, quality control, and safety Construct a prototype of a solution to a given design problem Given a design task, select appropriate materials based on specific properties needed in the construction of a solution
Grade Level	8th Grade
Learning Objectives	Students will investigate the relevance of their designs and the effect that they can have on a community. Students will learn and apply civil engineering terminology such loading, tension, compression, span, support, joint, connection, abutment, footing. They will be able to practice using that terminology as well as the civil engineering design process when building a prototype. They will design structures that account for several restraints (i.e. space and weather conditions). Students will design structures that maximize volumetric space with scarce materials as well as handle max loads in case of harsh weather conditions. Students will visualize how building this prototype stimulates the role that they can have as a civil engineer in the real world.
Sample Activity	Students will be given a presentation about civil engineers, their tasks, and their impact on society. They will also be taught civil engineering terminology (loading, tension, compression, span, support, joint, connection, abutment, footing) as well as the civil engineering design process (Define the Problem, Do Background Research, Specify Requirements, Brainstorm Solutions, Choose the Best Solution, Do Development Work, Build a Prototype, Test and Redesign). Students will be given the problem of designing a building that they can build using K'NEX that would be beneficial in a rural community. Designs must comply with space specifications and survive different weather patterns such as strong winds or cold weather. Students will follow the design process to build their prototype. They will document their journey following the design process and they will share that with the rest of their peers. The students will then all share their experience from the workshop as well as discuss how they can make an impact community based on the knowledge gained from their workshop experience.
Industry Connection	Structures must be built with the regional climate in mind in order to withstand harsh conditions and keep people safe. Civil engineers have the ability to build cost effective structures that can endure harsh weather patterns that are common in many communities around the world.

Chapter 5: Conclusions and Recommendations

In this chapter, we discuss our final thoughts on what we produced and how we recommend using it. We begin by discussing the Office of POP's desire to increase the number of STEM fields covered in Camp Reach. We also discuss effective STEM programming methods and our analysis of the effectiveness of past Camp Reach activities. Additionally, we provide an explanation of our primary deliverable, the module, as well as a recommendation of its utility. Finally, we explore the limitations of our project as well as its contribution to expanding the Camp Reach program.

Take advantage of the opportunity to introduce more STEM fields. The program's goal is to introduce women to STEM fields and to sustain their interest. National statistics indicate that the fields with the lowest percentage of women working in them are chemistry, environmental engineering, chemical engineering, civil engineering, industrial engineering, physics, electrical engineering, and mechanical engineering. These career fields, in addition to some effective ones from previous years at Camp Reach, were the ones that we chose to include in our recommended content for the Office of POP to develop a program. In the future, if the POP Office wants to include more STEM fields in the program, we recommend that they include fields that have a high ratio of women, as it is important to sustain female presence in the fields that have them already.

Increase emphasis on relevance and creativity. We incorporated relevance and creativity into our program content to help provide an engaging STEM summer experience. We found multiple methods for engaging females in STEM applications as well as sustaining their interest. The main ones that are useful for engaging young girls in STEM are eliminating bias through counterexample, providing strong female role models, and properly engaging and developing girls' talent in STEM areas (Meadows, 2016). Another essential aspect of the engagement process is providing positive experiences associated with STEM. Adolescents do not see math and science courses as an opportunity for creativity and design. They also do not see the relevance of their course work or its application to the real world (Cooper and Heaverlo, 2013). Girls tend to focus on creativity and real-world applications. However, if they do not draw the connection between STEM and these characteristics, they will not be interested in STEM fields.

Explore the effectiveness of past Camp Reach activities. From the survey data of past Camp Reach activities, we extracted quantitative ratings of each activity led in Camp Reach since 2008 to use as a reference for successful activities. This analysis resulted in a single number rating for each activity that incorporates enjoyment and learning from all three surveyed groups – campers, teaching assistants, and middle school teachers. The data we gathered gives the Office of POP and ourselves insight into the quality and success of the previous activities. Our advice for using this data is to treat the number rating as a guide instead of an absolute rating of that activity plan. When reviewing this data, we recommend program creators also consider the surveys, instructors, and resources students since these factors can largely influence the success of an activity.

STEM activity guidelines for effective programming. We developed a set of 25 modules for the POP Office to use when developing activities for future Camp Reach programs. Each module consists of seven subsets, which they should utilize during their program creation in the following ways.

1. **STEM Field**: This helps them find modules related to the STEM field the POP Office wish to program.
2. **Social Relevance**: This subset is a very important piece in the utilization of the module, as it both lays the groundwork for an activity and motivates middle school girls to learn about engineering by making a connection to helping others. We highly recommend the POP Office keep this subset as it is or very similar when creating activities for this reason.
3. **Academic Knowledge**: The Office of POP should use this subset as background knowledge on the middle school students when modifying or creating activities to ensure that they do not introduce too much or too little unknown information.
4. **Grade Level**: The POP Office should take this as only a suggestion, as it purely consists of the related academic knowledge that students should have from formal schooling. A modified activity may require different background knowledge. In this case, they should consult Massachusetts Department of Elementary and Secondary Education standards in Appendices B and C when selecting an appropriate grade level for the activity.
5. **Learning Objectives**: These are the main takeaways students should have about what engineers do, how they do it, and why it matters to the students and to the world. Therefore, these are as important as the social relevance to the overall module, and we recommend keeping consistent themes in all the learning objectives of all the modules.
6. **Sample Activity**: These samples focus mainly on incorporating the learning objectives above. We recommend the Office of POP do the same in their programming, either by using the samples as they are or modifying them as necessary, while still presenting similar learning objectives for the sake of improving STEM interest.
7. **Industry Connection**: The POP Office should use this portion to inform campers who want to continue in this field about potential careers they may seek out. They should also make activity presenters and supervisors very familiar with this information, because the students may look to them as role models.

Recommendation for utility of modules. We recommend that when the Office of POP utilizes the modules to build a summer program, they search for the appropriate grade level and see which activities that grade bank provides. If they like the activity but want to utilize it for a different grade level, they can modify the content to be age appropriate for another grade level, as we provided the educational curriculum for each age. Therefore, they can use the summary of the STEM curriculum to modify the activities if needed. Additionally, we recommend that if program schedulers choose a sample activity, they should adjust the activity to fit their program needs and resources more appropriately.

Limitations of project deliverables. The main limitation of the content in the developed modules is that we did not do an exhaustive search of resources. Due to the relative size of the team and the nature of the project, we chose the best resources that we found in order to gain information and insight. This included recommended websites and papers from our advisors and legitimate ones found by team members during the initial search. However, there are copious amounts of information that the Office of POP may utilize in order to develop more activities than just the ones presented. There are also some limitations to the provided ratings about the previous workshops in Camp Reach. The activities that rated poorly are not necessarily bad ideas in general. Rather, the POP Office could improve upon these and bring them to a higher standard before scheduling them again in the future. Another limitation is that we based the rating system used purely on people's responses to surveys. The person who presented that specific activity and how they did so could create a negative bias and a poor rating without said rating relating to the activity or topic idea itself.

Extension of opportunities for middle school girls. The resources created for the Office of POP enables them to develop an extended set of programs more easily, thus allowing more girls to attend and get involved in STEM. The framework developed includes three programs rather than one, increases the capacity from 30 to 90 girls, and includes 25 workshops rather than 10. Additionally, we included three more STEM fields that were not covered in the previous program. Increasing participation and potentially maintaining interest is a step toward solving more of the world's greater problems by further diversifying STEM fields.

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Appendix A: Office of POP Interview

POP Interview Protocol
Interviewers: YaYa Brown, Will Lucca
Interviewee: Sue Sontgerath

Hi Sue, thank you for meeting with us today. As one of our advisors in this IQP we've been able to hear your input throughout the process of developing the recommendation. However, to get a better sense of what you are looking for we would like to ask you a few questions pertaining to what to include in the recommendation. Throughout this interview we will be asking you follow up as well as clarification questions if that is okay with you. You are also welcome to ask us any questions.

If it is okay with you, we will be writing notes on the answer that you give us as a reminder about what was discussed during this interview.

1. Since the service project will not be implemented in the programs for 6th and 7th graders, should we find a replacement for it in the form of a project that teaches the design process and is throughout the time of the program?
    - Not necessary
    - If we found something great for 7th graders that teaches the engineering design process as well as fits in naturally then definitely include it in the recommendation
        - It shouldn't take too much time out of their day if we did want to recommend something
2. In previous meetings we know that you would like us to provide information on who ideal presenter of an activity should be. When considering this we know you are also limited in who you can find. How specific should that recommendation be and do you have recommendations for specific types of activities?
    - Have a baseline assumption a middle school teacher could be presenting this activity
    - If we find activities that a undergraduate student could teach then we can incorporate a different role model
    - Other activities may need more technical knowledge and so the presenter should be someone such as a graduate student
    - Don't limit ourselves to thinking too much about diversity of presenters, think that our recommendation would be the ideal situation and presenters may change.
3. Are there any types of STEM fields that you were unable to include due to time constraints that you would want included in future years?

   - Wants recommendations for more sophisticated computer work
   - Try to find activities that are outside the overdone science projects done in school for civil engineering or industrial engineering

4. This is our rubric for selecting and rating potential activities. In cases where we do not provide specific activity suggestions, we leave the activity selection up to POP. Do you feel this rubric sufficiently covers the essentials?
   - Provide a lot more explanation on what constitutes a high rating and the rating scale
   - Can use our own rubric when selecting activities to test it and make adjustments as necessary. Include these tests in the report
5. We have brought an example of one of the modules that would be in our final recommendation.
   - Change age level to grade level
   - Change activity topic to something that shows it's the action that the participants will be doing
   - First four sections (Grade Level, STEM Field, Academic Context, Problem) most important aspects
   - Last two section (Activity topic, sample activity) can be seen as optional
   - Overall, have more of an explanation of what everything means

(S. Sontgerath, personal communication, November 5, 2018).

Appendix B: Formal Schooling Part I

5th Grade Science, Technology, and Engineering Curriculum

Subject	Topic	Description
Earth and Space Science	Earth's Place in the Universe Earth's Systems Earth and Human Activity	Use observations, first-hand and from various media, to argue that the Sun is a star that appears larger and brighter than other stars because it is closer to Earth Use a model to communicate Earth's relationship to the Sun, Moon, and other stars that explain (a) why people on Earth experience day and night, (b) patterns in daily changes in length and direction of shadows over a day, and (c) changes in the apparent position of the Sun, Moon, and stars at different times during a day, over a month, and over a year. Use a model to describe the cycling of water through a watershed through evaporation, precipitation, absorption, surface runoff, and condensation Describe and graph the relative amounts of salt water in the ocean; freshwater in lakes, rivers, and groundwater; and freshwater frozen in glaciers and polar ice caps to provide evidence about the availability of fresh water in Earth's biosphere. Obtain and combine information about ways communities reduce human impact on the Earth's resources and environment by changing an agricultural, industrial, or community practice or process. Test a simple system designed to filter particulates out of water and propose one change to the design to improve it.
Life Science	From Molecules to Organisms: Structures and Processes Ecosystems: Interactions, Energy, and Dynamics	Ask testable questions about the process by which plants use air, water, and energy from sunlight to produce sugars and plant materials needed for growth and reproduction Develop a model to describe the movement of matter among producers, consumers, decomposers, and the air, water, and soil in the environment, with the emphasis being on how matter moves in the ecosystem Compare at least two designs for a composter to determine which is most likely to encourage decomposition of materials, with measures of decomposition being qualitative

Physical Science	Matter and Its Interactions Motion and Stability: Forces and Interactions Energy Technological Systems	Use a particle model of matter to explain phase changes Measure and graph the weights (masses) of substances before and after a reaction or phase change to provide evidence that mass is conserved Make observations and measurements of substances to describe characteristic properties of each, including color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility. Conduct an experiment to determine whether the mixing of two or more substances results in new substances with new properties (a chemical reaction) or not (a mixture). Support an argument with evidence that the gravitational force exerted by Earth on objects is directed toward Earth's center Use a model to describe that the food animals digest (a) contains energy that was once energy from the Sun, and (b) provides energy and nutrients for life processes, including body repair, growth, motion, body warmth, and reproduction. Use informational text to provide examples of improvements to existing technologies (innovations) and the development of new technologies (inventions). Recognize that technology is any modification of the natural or designed world done to fulfill human needs or wants.

6th Grade Science, Technology, and Engineering Curriculum

Subject	Topic	Description
Earth and Space Sciences	Earth's Place in the Universe Earth's Systems	1a. Develop and use a model of the Earth-Sun-Moon system to explain the causes of lunar phases and eclipses of the Sun and Moon 1b. Analyze and interpret rock layers and index fossils to determine the relative ages of rock formations that result from processes occurring over long periods of time 1c. Use graphical displays to illustrate that Earth and its solar system are one of many in the Milky Way galaxy, which is one of billions of galaxies in the universe 2a. Analyze and interpret maps showing the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence that Earth's plates have moved great distances, collided, and spread apart
Life Science	From Molecules to Organisms: Structures and Processes Biological Evolution: Unity and Diversity	1a. Provide evidence that all organisms (unicellular and multicellular) are made of cells 1b. Develop and use a model to describe how parts of cells contribute to the cellular functions of obtaining food, water, and other nutrients from its environment, disposing of wastes, and providing energy for cellular processes 1c. Construct an argument supported by evidence that the body systems interact to carry out essential functions of life. An example of interacting systems could include the respiratory system taking in oxygen from the environment which the circulatory system delivers to cells for cellular respiration, or the digestive system taking in nutrients which the circulatory system transports to cells around the body. 2a. Analyze and interpret evidence from the fossil record to describe organisms and their environment, extinctions, and changes to life forms throughout the history of Earth 2b. Construct an argument using anatomical structures to support evolutionary relationships among and between fossil organisms and modern organisms.

Physical Science	Matter and Its Interactions Motion and Stability: Forces and Interactions Waves and Their Applications in Technologies for Information Transfer	1a. Plan and conduct an experiment involving exothermic and endothermic chemical reactions to measure and describe the release or absorption of thermal energy 1b. Use a particulate model of matter to explain that density is the amount of matter (mass) in a given volume. Apply proportional reasoning to describe, calculate, and compare relative densities of different materials 1c. Conduct an experiment to show that many materials are mixtures of pure substances that can be separated by physical means into their component pure substances (i.e. vinegar and water) 2a. Use evidence to support the claim that gravitational forces between objects are attractive and are only noticeable when one or both of the objects have a very large mass (i.e. sun, earth) 3a. Use diagrams of a simple wave to explain that (a) a wave has a repeating pattern with a specific amplitude, frequency, and wavelength, and (b) the amplitude of a wave is related to the energy of the wave. 3b. Use diagrams and other models to show that both light rays and mechanical waves are reflected, absorbed, or transmitted through various materials. 3c. Present qualitative scientific and technical information to support the claim that digitized signals (sent as wave pulses representing 0s and 1s) can be used to encode and transmit information
Technology/ Engineering	Engineering Design Materials, Tools, and Manufacturing	1a. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution. Include potential impacts on people and the natural environment that may limit possible solutions 1b. Create visual representations of solutions to a design problem. Accurately interpret and apply scale and proportion to visual representations 2a. Analyze and compare properties of metals, plastics, wood, and ceramics, including flexibility, ductility, hardness, thermal conductivity, electrical conductivity, and melting point 2b. Given a design task, select appropriate materials based on specific properties needed in the construction of a solution 2c. Choose and safely use appropriate measuring tools, hand tools, fasteners, and common hand-held power tools used to construct a prototype

7th Grade Science, Technology, and Engineering Curriculum

Subject	Topic	Description
Earth and Space Sciences	Earth's Systems Earth and Human Activity	1a. Construct an explanation based on evidence for how Earth's surface has changed over scales that range from local (earthquake) to global (ice age) in size 1b. Develop a model to explain how the energy of the Sun and Earth's gravity drive the cycling of water, including changes of state, as it moves through multiple pathways in Earth's hydrosphere 2a. Obtain and communicate information on how data from past geologic events (earthquakes, floods) are analyzed for patterns and used to forecast the location and likelihood of future catastrophic events 2b. Construct an argument supported by evidence that human activities and technologies can mitigate the impact of increases in human population and per capita consumption of natural resources on the environment.
Life Science	From Molecules to Organisms: Structures and Processes Biological Evolution: Unity and Diversity	1a. Construct an explanation based on evidence for how characteristic animal behaviors and specialized plant structures increase the probability of successful reproduction of animals and plants. 2a. Analyze and interpret data to provide evidence for the effects of periods of abundant and scarce resources on the growth of organisms and the size of populations in an ecosystem. 2b. Describe how relationships among and between organisms in an ecosystem can be competitive, predatory, parasitic, and mutually beneficial and that these interactions are found across multiple ecosystems 2c. Develop a model to describe that matter and energy are transferred among living and nonliving parts of an ecosystem and that both matter and energy are conserved through these processes 2d. Analyze data to provide evidence that disruptions (natural or human-made) to any physical or biological component of an ecosystem can lead to shifts in all its populations 2e. Evaluate competing design solutions for protecting an ecosystem. Discuss benefits and limitations of each design 2f. Explain how changes to the biodiversity of an ecosystem—the variety of species found in the ecosystem—may limit the availability of resources humans use

Physical Science	Motion and Stability: Forces and Interactions Energy	1a. Analyze data to describe the effect of distance and magnitude of electric charge on the strength of electric forces (attractive and repulsive) 1b. Use scientific evidence to argue that fields (electrical, magnetic, gravitational) exist between objects with mass, between magnetic objects, and between electrically charged objects that exert force on each other even though the objects are not in contact 2a. Construct and interpret data and graphs to describe the relationships among kinetic energy, mass, and speed of an object 2b. Develop a model to describe the relationship between the relative positions of objects interacting at a distance and their relative potential energy in the system 2c. Apply scientific principles of energy and heat transfer to design, construct, and test a device to minimize or maximize thermal energy transfer 2d. Conduct an investigation to determine the relationships among the energy transferred, how well the type of matter retains or radiates heat, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. 2e. Present evidence to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. 2f. Use a model to explain how thermal energy is transferred out of hotter regions or objects and into colder ones by convection, conduction, and radiation. 2g. Use informational text to describe the relationship between kinetic and potential energy and illustrate conversions from one form to another

Technology/ Engineering	Engineering Design Technological Systems	1a. Evaluate competing solutions to a given design problem using a decision matrix to determine how well each meets the criteria and constraints of the problem. Use a model of each solution to evaluate how variations in one or more design features, including size, shape, weight, or cost, may affect the function or effectiveness of the solution. 1b. Generate and analyze data from iterative testing and modification of a proposed object, tool, or process to optimize the object, tool, or process for its intended purpose 1c. Construct a prototype of a solution to a given design problem 2a. Explain the function of a communication system and the role of its components, including a source, encoder, transmitter, receiver, decoder, and storage 2b. Compare the benefits and drawbacks of different communication systems 2c. Research and communicate information about how transportation systems are designed to move people and goods using a variety of vehicles and devices. 2d. Show how the components of a structural system work together to serve a structural function. Provide examples of physical structures and relate their design to their intended use. · Examples of components of a structural system could include foundation, decking, wall, and roofing. · Explanations of function should include identification of live vs. dead loads and forces of tension, torsion, compression, and shear. 2e. Use the concept of systems engineering to model inputs, processes, outputs, and feedback among components of a transportation, structural, or communication system.

8th Grade Science, Technology, and Engineering Curriculum

Subject	Topic	Description
Life Science	From Molecules to Organisms: Structures and Processes Heredity: Inheritance and Variation of Traits Biological Evolution: Unity and Diversity	1a. Construct an argument based on evidence for how environmental and genetic factors influence the growth of organisms 1b. Use informational text to describe that food molecules, including carbohydrates, proteins, and fats, are broken down and rearranged through chemical reactions forming new molecules that support cell growth and/or release of energy. 2a. Develop and use a model to describe that structural changes to genes (mutations) may or may not result in changes to proteins, and if there are changes to proteins there may be harmful, beneficial, or neutral changes to traits 2b. Construct an argument based on evidence for how asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. Compare and contrast advantages and disadvantages of asexual and sexual reproduction 2c. Communicate through writing and in diagrams that chromosomes contain many distinct genes and that each gene holds the instructions for the production of specific proteins, which in turn affects the traits of an individual 2d. Develop and use a model to show that sexually reproducing organisms have two of each chromosome in their cell nuclei, and hence two variants (alleles) of each gene that can be the same or different from each other, with one random assortment of each chromosome passed down to offspring from both parents. 3a. Use a model to describe the process of natural selection, in which genetic variations of some traits in a population increase some individuals' likelihood of surviving and reproducing in a changing environment. Provide evidence that natural selection occurs over many generations. 3b. Synthesize and communicate information about artificial selection, or the ways in which humans have changed the inheritance of desired traits in organisms

Physical Science	Matter and Its Interactions Motion and Stability: Forces and Interactions	1a. Develop a model to describe that (a) atoms combine in a multitude of ways to produce pure substances which make up all of the living and nonliving things that we encounter, (b) atoms form molecules and compounds that range in size from two to thousands of atoms, and (c) mixtures are composed of different proportions of pure substances. 1b. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. 1c. Develop a model that describes and predicts changes in particle motion, relative spatial arrangement, temperature, and state of a pure substance when thermal energy is added or removed. 1d. Use a model to explain that atoms are rearranged during a chemical reaction to form new substances with new properties. Explain that the atoms present in the reactants are all present in the products and thus the total number of atoms is conserved.
Technology / Engineering	Materials, Tools, and Manufacturing	1a. Use informational text to illustrate that materials maintain their composition under various kinds of physical processing; however, some material properties may change if a process changes the particulate structure of a material. 1b. Present information that illustrates how a product can be created using basic processes in manufacturing systems, including forming, separating, conditioning, assembling, finishing, quality control, and safety. Compare the advantages and disadvantages of human vs. computer control of these processes.

Earth and Space Sciences	Earth's Place in the Universe Earth's Systems Earth and Human Activity	1a. Develop and use a model of the Earth-Sun system to explain the cyclical pattern of seasons, which includes Earth's tilt and differential intensity of sunlight on different areas of Earth across the year. 1b. Explain the role of gravity in ocean tides, the orbital motions of planets, their moons, and asteroids in the solar system 2a. Use a model to illustrate that energy from Earth's interior drives convection that cycles Earth's crust, leading to melting, crystallization, weathering, and deformation of large rock formations, including generation of ocean seafloor at ridges, submergence of ocean seafloor at trenches, mountain building, and active volcanic chains. 2b. Interpret basic weather data to identify patterns in air mass interactions and the relationship of those patterns to local weather. 2c. Describe how interactions involving the ocean affect weather and climate on a regional scale, including the influence of the ocean temperature as mediated by energy input from the Sun and energy loss due to evaporation or redistribution via ocean currents. 3a. Analyze and interpret data to explain that the Earth's mineral and fossil fuel resources are unevenly distributed as a result of geologic processes. 3b. Examine and interpret data to describe the role that human activities have played in causing the rise in global temperatures over the past century.

(Mathematics: Grades Pre-Kindergarten to 12, 2017).

Appendix C: Formal Schooling Part II

5th Grade Math Curriculum

Topic	**Description**	**Example**
Operations and Algebraic Thinking	Writing and interpreting numerical expressions Using parentheses and brackets and evaluating expressions with these symbols Write expressions and interpret them without evaluation Analyzing patterns and relationships Identifying relationships between corresponding terms and graph ordered pairs	Express the calculation "Add 8 and 7, then multiply by 2" as 2 ´ (8 + 7). Recognize that 3 ´ (18932 + 921) is three times as large as 18932 + 921, without having to calculate the indicated sum or product.
Number and Operations in Base Ten	Understand the place value system Recognize that in a multi-digit number, including decimals, a digit in any place represents 10 times as much as it represents in the place to its right Use whole-number exponents to denote powers of 10. Read, write, and compare decimals to thousandths. Perform operations with multi-digit whole numbers and with decimals to hundredths. Fluently multiply multi-digit whole numbers Find whole-number quotients of whole numbers with up to four-digit dividends and two-digit divisors Find whole-number quotients of whole numbers with up to four-digit dividends and two-digit divisors	

Number and Operations-Fractions	Use equivalent fractions as a strategy to add and subtract fractions. Add and subtract fractions with unlike denominators Solve word problems involving addition and subtraction of fractions and use benchmark fractions and number sense of fractions to estimate mentally and assess the reasonableness of answers Apply and extend previous understandings of multiplication and division to multiply and divide fractions. Interpret a fraction as division of the numerator by the denominator Know how to multiply a fraction or whole number by a fraction. Comparing the size of a product to the size of one factor on the basis of the size of the other factor, without performing the indicated multiplication.	For example, $\frac{2}{3} + \frac{5}{4} = \frac{8}{12} + \frac{15}{12} = \frac{23}{12}$. (In general, $\frac{a}{b} + \frac{c}{d} = \frac{(ad + bc)}{bd}$.) For example, recognize an incorrect result $\frac{2}{5} + \frac{1}{2} = \frac{3}{7}$, by observing that $\frac{3}{7} < \frac{1}{2}$. For example, without multiplying tell which number is greater: 225 or ¾ x 225; $\frac{11}{50}$ or $\frac{3}{2}$ x $\frac{11}{50}$?
Measurement and Data	Convert like measurement units within a given measurement system. Being able to convert back and forth between meters, cm, km, etc. Represent and interpret data. Using line plots to interpret data and solve problems Geometric measurement: Understand concepts of volume and relate volume to multiplication and to addition. Measure volume by counting unit cubes, using cubic cm/in Apply the formula *V* = *l* ´ *w* ´ *h* and *V* = *B* ´ *h* Recognize volume as additive. Find volumes of solid figures composed of two non-overlapping right rectangular prisms by adding the volumes of the non-overlapping parts	For example, given different measurements of liquid in identical beakers, find the amount of liquid each beaker would contain if the total amount in all the beakers were redistributed equally.
Geometry	Graph points on the coordinate plane to solve real-world and mathematical problems. Understand that the first number indicates how far to travel from the origin in the direction of one axis, and the second number indicates how far to travel in the direction of the second axis, with the convention that the names of the two axes and the coordinates correspond (e.g., *x*-axis and *x*-coordinate, *y*-axis and *y*-coordinate). Classify two-dimensional figures into categories based on their properties. Understand that attributes belonging to a category of two-dimensional figures also belong to all subcategories of that category. Classify two-dimensional figures in a hierarchy based on properties.	For example, all rectangles have four right angles and squares are rectangles, so all squares have four right angles. For example, all rectangles are parallelograms because they are all quadrilaterals with two pairs of opposite sides parallel.

6th Grade Math Curriculum

Topic	Description	Example
Ratios and Proportional Relationships	Understand ratio and rate concepts and use ratio reasoning to solve problems. Use ratio language to describe a ratio relationship between two quantities. Understand the concept of a unit rate *a*/*b* associated with a ratio *a*:*b* with *b* ¹ 0, Use ratio and rate reasoning to solve real-world and mathematical problems	For example: The ratio of wings to beaks in the bird house at the zoo was 2:1, because for every two wings there was one beak; For every vote candidate A received, candidate C received nearly three votes, meaning that candidate C received three out of every four votes or ¾ of all votes. For example: This recipe has a ratio of three cups of flour to four cups of sugar, so there is ¾ cup of flour for each cup of sugar; We paid $75 for 15 hamburgers, which is a rate of five dollars per hamburger.
The Number System	Apply and extend previous understandings of multiplication and division to divide fractions by fractions. Interpret and compute quotients of fractions, and solve word problems involving division of fractions by fractions Compute fluently with multi-digit numbers and find common factors and multiples. Fluently add, subtract, multiply, and divide multi-digit decimals using the standard algorithm for each operation and use prime factorization to find the greatest common factor of two whole numbers Apply and extend previous understandings of numbers to the system of rational numbers. Understand where numbers lie on a number line as well as understanding the ordering and absolute value of rational numbers.	How many ¾-cup servings are in ⅔ of a cup of yogurt? For example, interpret –3 > –7 as a statement that –3 is located to the right of –7 on a number line oriented from left to right.
Expressions and Equations	Apply and extend previous understandings of arithmetic to algebraic expressions. Write expressions that record operations with numbers and with letters standing for numbers. Apply the properties of operations to generate equivalent expressions. Identify when two expressions are equivalent Reason about and solve one-variable equations and inequalities.	For example, express the calculation "Subtract y from 5" as 5 – y. For example, apply the distributive property to the expression 3(2 + x) to produce the equivalent expression 6 + 3x For example, the expressions y + y + y and 3y For example, in a problem involving motion at constant speed,

	Use substitution to determine whether a given number in a specified set makes an equation or inequality true. Represent and analyze quantitative relationships between dependent and independent variables. Use variables to represent two quantities in a real-world problem that change in relationship to one another	list and graph ordered pairs of distances and times, and write the equation d = 65t to represent the relationship between distance and time.
Geometry	Solve real-world and mathematical problems involving area, surface area, and volume. Find the area of right triangles, other triangles, special quadrilaterals, and polygons by composing into rectangles or decomposing into triangles and other shapes Find the volume of a right rectangular prism with fractional edge lengths by packing it with unit cubes of the appropriate unit fraction edge lengths Draw polygons in the coordinate plane given coordinates for the vertices; use coordinates to find the length of a side joining points with the same first coordinate or the same second coordinate	
Statistics and Probability	Develop understanding of statistical variability. Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers. Understand that a set of data collected to answer a statistical question has a distribution, which can be described by its center (median, mean, and/or mode), spread (range, interquartile range), and overall shape. Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number. Summarize and describe distributions. Display numerical data in plots on a number line, including dot plots, histograms, and box plots. Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered.	For example, "How old am I?" is not a statistical question, but "How old are the students in my school?" is a statistical question because one anticipates variability in students' ages.

7th Grade Math Curriculum

Topic	Description	Example
Ratios and Proportional Relationships	Analyze proportional relationships and use them to solve real-world and mathematical problems. Compute unit rates associated with ratios of fractions, Recognize and represent proportional relationships between quantities, and Use proportional relationships to solve multi-step ratio, rate, and percent problems	For example, if a person walks ½ mile in each ¼ hour, compute the unit rate as the complex fraction $\frac{1/2}{1/4}$ miles per hour, equivalently 2 miles per hour. For example: simple interest, tax, price increases and discounts, gratuities and commissions, fees, percent increase and decrease, percent error.
Number System	Apply and extend previous understandings of operations with fractions to add, subtract, multiply, and divide rational numbers. Describe situations in which opposite quantities combine to make zero, Understand subtraction of rational numbers as adding the additive inverse, $p - q = p + (-q)$, Understand $p + q$ as the number located a distance $\lvert q \rvert$ from p, in the positive or negative direction depending on whether q is positive or negative	For example: A hydrogen atom has zero charge because its two constituents are oppositely charged; If you open a new bank account with a deposit of $30 and then withdraw $30, you are left with a $0 balance.
Expressions and Equations	Use properties of operations to generate equivalent expressions. Apply properties of operations to add, subtract, factor, and expand linear expressions with rational coefficients. Understand that rewriting an expression in different forms in a problem context can shed light on the problem and how the quantities in it are related. Solve real-life and mathematical problems using numerical and algebraic expressions and equations	For example, 4x + 2 = 2(2x +1) and -3(x – $\frac{5}{3}$) = -3x + 5. For example, a + 0.05a = 1.05a means that "increase by 5%" is the same as "multiply by 1.05." A shirt at a clothing store is on sale for 20% off the regular price, "p". The discount can be expressed as 0.2p. The new price for the shirt can be expressed as p – 0.2p or 0.8p.
Geometry	Draw, construct and describe geometrical figures and describe the relationships between them. Solve problems involving scale drawings of geometric figures, such as computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale. Draw (freehand, with ruler and protractor, and with technology) two-dimensional geometric shapes with given conditions. Describe the shape of the two-dimensional face of the figure that results from slicing three-dimensional figures	

	Solve real-life and mathematical problems involving angle measure, area, surface area, and volume. Understand and describe the relationship among the radius, diameter, and area of a circle. Know the formulas for the area and circumference of a circle and use them to solve problems	
Statistics and Probability	Use random sampling to draw inferences about a population. Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions. Draw informal comparative inferences about two populations. Use measures of center and measures of variability for numerical data from random samples to draw informal comparative inferences about two populations. Investigate chance processes and develop, use, and evaluate probability models. Develop a uniform probability model by assigning equal probability to all outcomes, and use the model to determine probabilities of events. Develop a probability model (which may not be uniform) by observing frequencies in data generated from a chance process. Find probabilities of compound events using organized lists, tables, tree diagrams, and simulation.	For example, estimate the mean word length in a book by randomly sampling words from the book; predict the winner of a school election based on randomly sampled survey data. Gauge how far off the estimate or prediction might be. For example, decide whether the words in a chapter of a 7th grade science book are generally longer than the words in a chapter of a fourth-grade science book. For example, if a student is selected at random from a class, find the probability that Jane will be selected and the probability that a girl will be selected. For example, find the approximate probability that a spinning penny will land heads up or that a tossed paper cup will land open-end down. Do the outcomes for the spinning penny appear to be equally likely based on the observed frequencies? For example, use random digits as a simulation tool to approximate the answer to the question: If 40% of donors have type A blood, what is the probability that it will take at least four donors to find one with type A blood?

8th Grade Math Curriculum

Topic	**Description**	Example
The Number System	Know that there are numbers that are not rational, and approximate them by rational numbers Know that numbers that are not rational are called irrational. Understand informally that every number has a decimal expansion. Use rational approximations of irrational numbers to compare the size of irrational numbers, locate them approximately on a number line diagram, and estimate the value of expressions (e.g., p^2).	For example, by truncating the decimal expansion of show that is between 1 and 2, then between 1.4 and 1.5, and explain how to continue on to get better approximations.
Expressions and Equations	Work with radicals and integer exponents. Know and apply the properties of integer exponents to generate equivalent numerical expressions. Evaluate square roots of small perfect squares and cube roots of small perfect cubes Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notations are used Understand the connections between proportional relationships, lines, and linear equations. Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways. Derive the equation $y = mx$ for a line through the origin and the equation $y = mx + b$ for a line intercepting the vertical axis at b. Analyze and solve linear equations and pairs of simultaneous linear equations. variables correspond to points of intersection of their graphs, because points of intersection satisfy both equations simultaneously. Solve systems of two linear equations in two variables algebraically (using substitution and elimination strategies), and estimate solutions by graphing the equations.	For example, $3^2 * 3^{-5} = 3^{-3} = 1/3^3 = 1/27$. For example, compare a distance-time graph to a distance-time equation to determine which of two moving objects has greater speed. For example, 3x + 2y = 5 and 3x + 2y = 6 have no solution because 3x + 2y cannot simultaneously be 5 and 6.

Functions	1. Define, evaluate, and compare functions. 2. Understand that a function is a rule that assigns to each input exactly one output. The graph of a function is the set of ordered pairs consisting of an input and the corresponding output. 3. Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions 4. Interpret the equation $y = mx + b$ as defining a linear function whose graph is a straight line; give examples of functions that are not linear. 5. Use functions to model relationships between quantities 6. Construct a function to model a linear relationship between two quantities	For example, given a linear function represented by a table of values and a linear function represented by an algebraic expression, determine which function has the greater rate of change. For example, the function $A = s^2$ giving the area of a square as a function of its side length is not linear because its graph contains the points (1, 1), (2, 4) and (3, 9), which are not on a straight line.
Geometry	1. Understand congruence and similarity using physical models, transparencies, or geometry software. 2. Verify experimentally the properties of rotations, reflections, and translations: Understand that a two-dimensional figure is congruent to another if the second can be obtained from the first by a sequence of rotations, reflections, and translations. 3. Describe the effects of dilations, translations, rotations, and reflections on two-dimensional figures using coordinates. 4. Understand that a two-dimensional figure is similar to another if the second can be obtained from the first by a sequence of rotations, reflections, translations, and dilations. 5. Understand and apply the Pythagorean Theorem. 6. Understand the relationship among the sides of a right triangle. 7. Apply the Pythagorean Theorem to determine unknown side lengths in right triangles in real-world and mathematical problems in two and three dimensions. 8. Apply the Pythagorean Theorem to find the distance between two points in a coordinate system. 9. Solve real-world and mathematical problems involving volume of cylinders, cones, and spheres.	

Statistics and Probability	1. Investigate patterns of association in bivariate data. patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association. 2. Know that straight lines are widely used to model relationships between two quantitative variables. For scatter plots that suggest a linear association, informally fit a straight line and informally assess the model fit by judging the closeness of the data points to the line. Use the equation of a linear model to solve problems in the context of bivariate measurement data, interpreting the slope and intercept 3. Understand that patterns of association can also be seen in bivariate categorical data by displaying frequencies and relative frequencies in a two-way table. Construct and interpret a two-way table summarizing data on two categorical variables collected from the same subjects. Use relative frequencies calculated for rows or columns to describe possible association between the two variables.	For example, in a linear model for a biology experiment, interpret a slope of 1.5 cm/hr as meaning that an additional hour of sunlight each day is associated with an additional 1.5 cm in mature plant height. For example, collect data from students in your class on whether or not they have a curfew on school nights and whether or not they have assigned chores at home. Is there evidence that those who have a curfew also tend to have chores?

(2016 Massachusetts Science and Technology/Engineering Curriculum Framework, 2016).

Appendix D: Modules

Module Colors

- Biomedical Engineering
- Civil Engineering
- Computer Science
- Electrical Engineering
- Game Development
- Industrial Engineering
- Mechanical Engineering
- Chemical Engineering
- Physics
- Robotics

6th Grade Modules

STEM Field	Biomedical Engineering
Social Relevance	People often take pills to help them get better. The coating on these pills are vital in ensuring that medicine is not exposed to stomach acid which can cause it to become unstable because of various chemical properties. Other times pills must be released at specific parts in our digestive system tract to ensure it will work as it is intended.
Academic Knowledge	Students should have a basic understanding of the digestive system and its purpose in the human body.
Grade Level	6th, 7th, 8th
Learning Objectives	Students will examine why people take medicine and how important it is to people who are ill. Students will analyze the digestive system and be able to identify where stomach acid may cause an issue and what primary areas of the digestive system medicine should be released. Students will be able to identify the main reasons why pills need to have a coating on them: easier to swallow, preventing medicine from being released too quickly, preventing medicine from being released in an environment where it could be unstable. Students will be able to develop their own coating and see how mixing different combinations of dry and wet ingredients can create a better or worse pill coating.
Sample Activity	A patient with a sensitive stomach needs you to design a pill coating to prevent the medicine from being released into her stomach. Students will design a mock pill coating that must not dissolve in soda. The activity will start with an overview of the importance of medicine taken in the form of pills both for non-severe medical conditions as well as severe ones. A brief overview of the digestive system will be given, highlighting the different acidic levels. Students will be taught that acid is able to dissolve pill coatings faster causing the medicine to be released faster. The last slide should give the reasons why pills are coated. They will be given common household ingredients to mix together. This should include a mix of dry and wet ingredients such as olive oil, flour, corn starch, sugar, etc. They will then mix these ingredients to develop three different coatings. Throughout this mixing process they will write down and keep track of how much of each ingredient they used. They will then coat candies with a dyed outside layer (skittles, M&Ms, etc.) with their pill coatings and put them into three different cups each with a type of soda in them. Wait for 10 minutes and then see if the candy has lost its coating or not.
Industry Connection	How medicine is delivered into our system is just as vital as the medicine itself. Without taking careful consideration to how medicine is delivered can cause it to be ineffective or even harmful to the human body. Biomedical engineers are able to use both chemistry as well as their knowledge of the human body to develop devices and things that must work with the chemicals that our body produces.

STEM Field	Biomedical Engineering
Social Relevance	Accidents as well as other medical conditions can leave a person physically disabled. They are then unable to perform tasks the same way as before and, in some cases, need assistance to do things tasks that we don't even think about such as holding a paintbrush.
Academic Knowledge	Students should understand how to take specifications for a device and both design and develop a working prototype.
Grade Level	6th, 7th, 8th
Learning Objectives	Students will value that assistive devices are needed by physically disabled people and they use them out of necessity and not out of choice. Students will be able to utilize the engineering design process to design a device having certain specifications due to how it will be used and who the user is.
Sample Activity	Students will be given an introductory overview of imagining themselves unable to use their hands and how that might affect their lives. They will then be introduced to the concept that engineers are able to design devices that can improve a person's quality of life. Students will then be challenged to use the engineering design process in teams to develop a device with certain criteria. This being lightweight, inexpensive, safe, durable, able to attach to hand or wrist, and able to hold a small paint brush or drawing instrument. They will then be given a list of available materials. They will generate an idea of a design, prepare a list of materials, construct a prototype, and test and evaluate their device. Possible redesign might have to happen based on user feedback. The last portion of this activity will focus on having the campers share their designs and the process they went through to get to their final design.
Industry Connection	Biomedical engineers are able to give physically disabled people the ability to continue living normal lives and to continue doing their passions. They blend together their knowledge about the human body with things such as mechanical engineering in order to create the perfect device that suits the need of the individual.

STEM Field	Biomedical Engineering
Social Relevance	When repairing broken bones some doctors need devices that are able to aid in the healing of these bones correctly and to not limit mobility of the person having to wear these fixtures.
Academic Knowledge	Students should know what bones are in the body and their main purpose.
Grade Level	6th, 7th, 8th
Learning Objectives	Students will be able to explain that bones are both strong and flexible which is why it's hard to repair or mimic their function perfectly. Students will be able to explain that the materials for bone fixing needs to be made of specific material such as stainless steel, titanium alloys, and polymers. Students will be able to explain that biomedical engineers aid doctors when a break needs to be able to restore function, likely to not heal correctly, high risk of infection, and long healing time. Students will use the engineering process to create prototypes that are able to repair a broken bone.
Sample Activity	Students will be given a presentation where the properties of bones are discussed. They will also be asked what materials they think are best used to recreate the function of bones and why this is. Materials: Femur bones (turkey), Screwdriver, Screws, Rods, Plates Students are given femur bones (turkey) and then they are broken using weights and the amount of weight that caused the bone break is recorded. They are then given a list of material they can use to fix the bone and are tasked with prototyping possible ways to repair the broken bones This will include drawing the design out with accurate scaling. They will then try to repair the bones using given materials and following their design. Design changes can be made throughout the process but must be justified. Then the bones are tested once again to see if they can hold up to the same weight or more. (this is a long project and probably would be better implemented in 7th grade or 6th grade.)
Industry Connection	Serious medical emergencies happen every day to people. This can be a failing organ, bodily functions that are not operating properly, etc. Biomedical engineers are able to aid in these types of emergencies and are currently trying to develop devices that can replace the function of an organ. Or other devices that are able to go into the human body to either help it function normally or replace it.

STEM Field	Civil Engineering
Social Relevance	Public art structures require a lot of time, resource, and energy investments. Due to strict budgeting, there are not a lot of resources that are allocated to build artistic structures.
Academic Knowledge	Geometry: • Draw polygons in the coordinate plane given coordinates for the vertices • Solve real-world and mathematical problems involving area, surface area, and volume. Engineering Design: • Create visual representations of solutions to a design problem. Accurately interpret and apply scale and proportion to visual representations. • Given a design task, select appropriate materials based on specific properties needed in the construction of a solution
Grade Level	6th Grade
Learning Objectives	Students will discover civil engineers' tasks and the impact that they have on society. Students will be draw polygons and calculate their areas and volumes. They will use that knowledge to design an art piece. Students will also use their drawings of the polygons to design an art piece using the design process of civil engineers. They will make a blueprint of their design, specify a scale, and choose the materials that they need for their project based on the properties they chose. Students will visualize how building this artistic structure stimulates the role that they can have as a civil engineer in the real world
Sample Activity	Students will be given a presentation about civil engineers, their tasks, and their impact on society. The presentation will also focus on the artistic competency that civil engineers have. The presentation will also reveal artistic structures that different engineers have built. Students will be split into teams. Each team will represent a developing country. The teams will be told about their respective country's culture as well as shown some artistic pieces from that culture. The students will then be given a presentation about how to draw polygons when given vertices and they will calculate the areas and volumes of those polygons. The students will use the shapes they drew for inspiration to draw a blueprint of a mosaic that use those shapes. They will also come up with a scale. They will also specify properties of their 3D mosaic and choose materials based on those properties. Finally, they will build the 3D mosaic and then present to the rest of the students about their inspiration, the properties they chose, as well as the materials they selected. They will also talk about how their art piece symbolizes their respective culture. The students will then all share their experience from the workshop as well as discuss how they can make an impact on their respective developing countries based on their workshop experience.
Industry Connection	Civil engineers are very efficient when building structures. They can design significant artistic structures that also meet budget constraints.

STEM Field	Computer Science
Social Relevance	In this digital world it is becoming easier and easier to impersonate someone else by stealing their information. Important data needs to be protected and verifiable.
Academic Knowledge	Mathematical Operations: use parentheses and brackets to evaluate expressions Numbers and Operations in Base Ten: fluently perform multiplication and division with multi-digit numbers
Grade Level	6th, 7th
Learning Objectives	Students will be able to apply their knowledge of numerical operations to evaluate expressions that encode and decode messages using basic ciphers. Students will be able to design their own variations on these ciphers. Students will analyze the role of cybersecurity engineers in designing algorithms for encrypting data. Students will recognize the importance of designing secure encryption algorithms that cannot be solved by others.
Sample Activity	Ciphers, Codebreaking, and Codemaking: Teach students about the Caesar cipher. They can try using the Caesar cipher with a small key (maybe a number between 1 and 5) to encode messages, then attempt to decode the messages of others without knowing the key. Once they have successfully decoded some, explain how this algorithm for encrypting a message is not very secure even without the key and would take a computer no time at all to crack. Next, introduce the Affine cipher. Have students create encrypted messages again following the numerical operations of the algorithm with any key values they like. Have them briefly look at the encrypted message to find patterns as they did with the Caesar encryptions. When they are unable to find any, explain how this is more complicated to crack without the key values. Finally, encourage students to design their own simple ciphers. A single mathematical operation on the numbers corresponding to the letters in their message is enough for these ciphers. Have them challenge each other to decode their own encrypted messages. This makes the connection to being a cybersecurity engineer, designing algorithms that obscure their inner workings, unlike the Caesar cipher, to encode files and keep them safe.
Industry Connection	Passwords are used for all types of accounts in many parts of our lives, from social media to work and to even bank accounts. This information is extremely valuable to every individual who uses the internet, and as long as it exists online, it should be safe behind digital keys and authorizations. Cybersecurity engineers design systems and algorithms to protect this information so that no one can access the decrypted data.

STEM Field	Computer Science
Social Relevance	Computer generated animations are often necessary in videos and movies for entertainment and educational purposes.
Academic Knowledge	Geometry and the Coordinate Plane: understand how to plot points in the coordinate plane using the x and y axes and x, y coordinates
Grade Level	6th, 7th, 8th
Learning Objectives	Students will apply their knowledge of graphing in the coordinate plane to move and control sprites in Scratch. Students will be able to create an animation using Scratch. Students will be able to author simple executable scripts using drag-and-drop pieces with no variable or loops. Students will recognize the fact that computer scientists can use computer scripts to make virtual objects and characters move without having to draw the characters over and over one-at-time.
Sample Activity	Creating Animations Using Scratch: Begin by teaching students how to write scripts in Scratch. Introduce them to movement code blocks, costume/sprite changing code blocks, and other visual effects only. Explain how computers treat the top of the screen as y = 0, and down is the positive y direction. Then, the students can then create short animations in teams by combining the movement of objects around the coordinate plane with visual effects in a logical flow. The animations themselves can be comedic, tell a story, teach something, or more. Once the teams are happy with their animations, they should be shown to the whole group. This presentation serves as incentive to make something entertaining. Make the connection that a computer scientist could have similar tasks in real life, using code to animate shapes and images for a whole range of applications, from the UI in one's phone, to the next Disney movie.
Industry Connection	We encounter virtual animations all the time in everyday electronics like our phones and computers. User interfaces are often animated to make them more understandable and appealing. Most movies in theaters today use computer animation in some degree as well. Computer scientists use computer instructions to create the animations as they appear.

STEM Field	Electrical Engineering
Social Relevance	Communications is an important part of our everyday lives and it gives us the ability to connect everyone together. However, the process of transferring data is complex. Therefore, if there is not remediation for these complications, communication with people around the world can be limited. Failures in communications networks can have severe consequences.
Academic Knowledge	Students should be able to understand what it means to effectively communicate.
Grade Level	6th
Learning Objectives	Students will create a basic block diagram of communications system from a transmitter to a receiver in order to examine how a message travels. Transmitter ⇒ channel ⇒ receiver Students will recreate basic MAC protocols including exponential back-off, carrier-sense multiple access with collision avoidance and carrier-sense multiple access with collision detection in order to examine how MAC protocols function. Students will observe the interference of messages when data is being sent at the same time in the same frequency by seeing how much of a conversation they are able to comprehend when people are talking at the same time. Students will connect how verbal communication can be similar to how wireless devices talk to each other through recreating and creating their own MAC protocols.
Sample Activity	Students will be given a brief lecture of the about wireless communication. The first part of the lecture will go over the block diagram of a basic communication system. Then it will introduce that interference can occur when two messages are trying to be sent at the same time and that data corruption could occur. The last part of the slide will introduce MAC protocols which are protocols that have been or are being used to decrease the likelihood of messages. Exponential back-off: send messages at random times in hopes that because their all random collisions will not occur Carrier-sense Multiple Access with collision avoidance: the transmitter will "see" if the channel is idle and only send messages then Carrier-sense Multiple Access with collision detection: the transmitter will be able to sense if other transmitters are also sending data and send a jam signal if a collision occurs. It will then wait a random amount of time and try to send the data again. After a brief explanation about each MAC protocol students will form groups of three and attempt to follow the protocol or "rules" for when they are talking. They will then come up with their own protocols this is a random set of rules to follow when talking. They will then see which protocol is able to get the most information out in the shortest amount of time, which is the best to get out everyone's information fairly, and which is the easiest to implement.
Industry Connection	Electrical engineers and more specifically communication engineers help make this connection more efficient as well as accurate. They are involved in the design of what a signal will look like traveling wirelessly and how to decode and receive it and make sense of a received signal in order to translate it back to what it was.

STEM Field	Game Development
Social Relevance	Stories, both fictional and historical, serve as methods to educate people, create ideas, and escape reality. Many songs, poems, and artworks incorporate stories to immerse the audience into a different world or time period. A game is an example of an art form that often relies heavily on storytelling.
Academic Knowledge	Essay writing: the ability to articulate thoughts in organized writing Story writing: storytelling skills that incorporate the five senses, character traits, and interaction between characters and environments
Grade Level	6th Grade
Learning Objectives	Students will visualize how game developers can create games that immerse players in another world. Students will be able to create compelling backstories given a specific character, setting, or scenario. Students will analyze the game developing process, specifically the creative process.
Sample Activity	Present students with the types of processes and roles within game development. "What is game development?" Discuss specific games (either predetermined or suggested by students) and what went in to creating them. Provide students a drawing of a character, object, or setting. Students create a story or explain the backstory. Discuss creations and how they might be used to create a game. "What types of games would you make from this?"
Industry Connection	Game Developers identify what stories, game mechanics, and visuals attract their target audience and create the most intriguing game they can for those people. Their games can incorporate social issues and psychology to create a piece of work that is not only entertaining but provokes further thought about the world.

STEM Field	Industrial Engineering
Social Relevance	Clothing items that we purchase daily are defective and overpriced due to lack of standardized and efficient processes in the fashion industry.
Academic Knowledge	Number and Operations in Base Ten: Perform operations with multi-digit whole numbers and with decimals to hundredths. Compute fluently with multi-digit numbers. Statistics and probability: Display numerical data in plots on a number line, including dot plots, histograms, and box plots. Materials, tools, and Manufacturing: Given a design task, select appropriate materials based on specific properties needed in the construction of a solution
Grade Level	6th Grade
Learning Objectives	Students will apply basic engineering principles such as the importance of time, and quality control, and proper use of resources. Students will use their knowledge of performing operations and computing with multi digit numbers to analyze the time it takes to perform processes. They will also be able to plot the number of defects they produce on a plot and analyze the data. Finally, they are going to select appropriate materials to build the prototype while being efficient in order to not create waste. Students will experiment with different processes and reflect on the impact they individually made on the process and how their tasks can be applied to the real world.
Sample Activity	Fashion Show: Students will be introduced with information about what industrial engineers do, the industries that they are a part of, and information about the daily tasks they perform. They will also be presented with information about how industrial engineers time processes, improve quality, and have to efficiently allocate resources. Students will be given the task to put on a runway show. They will form teams with each team member having a different role. Each team will have a timer, a quality inspector, a model, and assembly line workers that will put together the outfit. Once they have their roles, the students will be given a design that they have to make out of their given resources. Students will write down in steps their process to make the product including the resources they need and the respective quantities of materials. Teams will perform multiple trials, each time modifying their process to improve it. Teams will keep a log of all process modifications. During each trial they must record the time each step takes. They must also count the number of defects that they produce during each trial (the number of differences between the design and the actual product they build) and record that number. They must also count the amount of wasted resources after each trial and record that data. Using the recorded data, they will plot the process times of each trial, the quality data of each trial, and material waste of each trial. They will then analyze all those plots to determine which process was the most efficient. The models in the team will walk in a runway show wearing the prototype from the most efficient process and the teams will discuss their data regarding that process. The students will then all share their experience from the workshop as well as discuss how they can make an impact in the real world based on their learning in the workshop.
Industry Connection	Industrial engineers have the ability to modify processes, making them more efficient. Increase in efficiency decreases costs, and decreasing price makes items more affordable for the public.

STEM Field	Mechanical Engineering
Social Relevance	Many people need prosthetics to function but do not have access to and cannot afford such services.
Academic Knowledge	Engineering Design: create visual representations of solutions to a design problem. Interpret and apply scale to visual representations
Grade Level	6th, 7th, 8th
Learning Objectives	Students will be able to formulate a visual solution to a given engineering problem that requires a 3D model. Students will be able to create a simple 3D model in SolidWorks and 3D print it. Students will recognize the applications of 3D printing and the role mechanical engineers typically have in designing and printing parts.
Sample Activity	SolidWorks and 3D Printing: Show students box-modeling techniques to create a model of their own in SolidWorks. Explain how engineers can use this to model parts for their projects, like prosthetics for people, as they will soon be printed into reality using this program. They are then posed an engineering problem: creating a model of an existing toy, like a top, Legos, dolls, etc. It can be anything they come up with, as long as it follows this theme, so that they are small and can be printed easily. Have students first hand-draw their ideas for their model, then move into SolidWorks once they all have a plan. Help students create their models, and then help them send the files to the 3D printers to start printing them. Explain that this is the very same process mechanical engineers use to 3D print parts for their own designs for all sorts of projects, including prosthetics with various materials. The use of toys as the problem means that the students will have something fun to take home, and that they realize the humanistic value of 3D printers firsthand.
Industry Connection	3D printing provides a cheap solution to many problems beyond prosthetic devices for rehabilitation, including manufacturing products with many different materials, and prototyping new technologies to benefit the world in a relatively cheap process. A mechanical engineer would use 3D printing to create physical prototypes or parts for machines of their design.

STEM Field	Mechanical Engineering
Social Relevance	Many people need prosthetics to function but do not have access to and cannot afford such services.
Academic Knowledge	Engineering Design: create visual representations of solutions to a design problem. Interpret and apply scale to visual representations
Grade Level	6th, 7th, 8th
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7th Grade Modules

STEM Field	Biomedical Engineering
Social Relevance	Accidents as well as other medical conditions can leave a person physically disabled. They are then unable to perform tasks the same way as before and in some cases need assistance to do things tasks that we don't even think about such as holding a paintbrush.
Academic Knowledge	Students will understand how to take specifications for a device and both design and develop a working prototype.
Grade Level	6th, 7th, 8th
Learning Objectives	Students will value that assistive devices are needed by physically disabled people and they use them out of necessity and not out of choice. Students will be able to utilize the engineering design process to design a device having certain specifications due to how it will be used and who the user is.
Sample Activity	Students will be given an introductory overview of imagining themselves unable to use their hands and how that might affect their lives. They will then be introduced to the concept that engineers are able to design devices that can improve a person's quality of life. Students will then be challenged to use the engineering design process in teams to develop a device with certain criteria. This being lightweight, inexpensive, safe, durable, able to attach to hand or wrist, and able to hold a small paint brush or drawing instrument. They will then be given a list of available materials. They will generate an idea of a design, prepare a list of materials, construct a prototype, and test and evaluate their device. Possible redesign might have to happen based on user feedback. The last portion of this activity will focus on having the campers share their designs and the process they went through to get to their final design.
Industry Connection	Biomedical engineers are able to give physically disabled people the ability to continue living normal lives and to continue doing their passions. They blend together their knowledge about the human body with things such as mechanical engineering in order to create the perfect device that suits the need of the individual.

STEM Field	Biomedical Engineering
Social Relevance	When repairing broken bones some doctors need devices that are able to aid in the healing of these bones correctly and to not limit mobility of the person having to wear these fixtures.
Academic Knowledge	Students should know what bones are in the body and their main purpose.
Grade Level	6th, 7th, 8th
Learning Objectives	Students will be able to explain that bones are both strong and flexible which is why it's hard to repair or mimic their function perfectly. Students will be able to explain that the materials for bone fixing needs to be made of specific material such as stainless steel, titanium alloys, and polymers. Students will be able to explain that biomedical engineers aid doctors when a break needs to be able to restore function, likely to not heal correctly, high risk of infection, and long healing time. Students will use the engineering process to create prototypes that are able to repair a broken bone.
Sample Activity	Students will be given a presentation where the properties of bones are discussed. They will also be asked what materials they think are best used to recreate the function of bones and why this is. Materials: Femur bones (turkey), Screwdriver, Screws, Rods, Plates Students are given femur bones (turkey) and then they are broken using weights and the amount of weight that caused the bone break is recorded. They are then given a list of material they can use to fix the bone and are tasked with prototyping possible ways to repair the broken bones This will include drawing the design out with accurate scaling. They will then try to repair the bones using given materials and following their design. Design changes can be made throughout the process but must be justified. Then the bones are tested once again to see if they can hold up to the same weight or more. (this is a long project and probably would be better implemented in 7th grade or 6th grade.)
Industry Connection	Serious medical emergencies happen every day to people. This can be a failing organ, bodily functions that are not operating properly, etc. Biomedical engineers are able to aid in these types of emergencies and are currently trying to develop devices that can replace the function of an organ. Or other devices that are able to go into the human body to either help it function normally or replace it.

STEM Field	Chemical Engineering
Social Relevance	Clear, drinkable water is a scarce resource in many areas around the world.
Academic Knowledge	Physical Science: Conduct an experiment to determine whether the mixing of two or more substances results in new substances with new properties (a chemical reaction) or not (a mixture) Life Science: Knowledge of bacteria and colonies and colony counting Engineering Design: Evaluate competing solutions to a given design problem using a decision matrix to determine how well each meets the criteria and constraints of the problem
Grade Level	7th Grade
Learning Objectives	The students will relate chemical engineering to developing water filtration methods. The students will use their knowledge about chemical reactions to modify the properties of a substance. They will also use their knowledge of colony counting to compare two design options and determining which is the prime solution. Students will visualize how building a water filtration process stimulates the role that they can have as a chemical engineer in the real world.
Sample Activity	Students will be given a presentation about chemical engineers, their tasks, and their impact on society. They will also be presented with base knowledge that they need to know about chemical reactions and bacteria and colony counting. Students will be asked to compare different water filtration processes that utilize organic chemicals. They will gather a sample of pond water and use petri dishes to host the bacteria from the pond sample. They will then split the sample into three. They will put bentonite clay in one, magnesium chloride in the other, and a combination of both in the last one. They will then collect bacteria from each sample and put it on a petri dish. The students will count the number of colonies in each petri dish and discover which dish had the smallest number of colonies. They will use a decision matrix based on cost and effectiveness of the different chemicals. They will choose the ideal solution. The students will share their results as well as their observations about the chemical reaction. (It is best if an instructor demonstrates the activity before the students try it on their own) Students will also reflect as a group about what they learned from the workshop as well as how their knowledge can be applied to a community. They will also discuss how they developed a system from organic materials that are abundant all around the world.
Industry Connection	Chemical engineers have the ability to develop water filtration methods are inexpensive and can provide a scarce resource to communities with little resources.

STEM Field	Civil Engineering
Social Relevance	Many of our homes have decorative structures such as chandeliers, ceiling fans, and clocks. These decorative structures need to be secure in order to ensure safety.
Academic Knowledge	Physical Science: • Use scientific evidence to argue that fields (electrical, magnetic, gravitational) exist between objects with mass, between magnetic objects, and between electrically charged objects that exert force on each other even though the objects are not in contact • Use informational text to describe the relationship between kinetic and potential energy and illustrate conversions from one form to another Engineering Design: • Construct a prototype of a solution to a given design problem
Grade Level	7th Grade
Learning Objectives	Students will relate art and engineering when developing designs. They will design and build a structure. They will also be able to describe forces that are acting on their structure as well as be able to discuss the transfer of kinetic energy to potential energy and vice versa in their structure. Students will visualize how building this artistic structure stimulates the role that they can have as a civil engineer in the real world.
Sample Activity	Students will be given a presentation about civil engineers, their tasks, and their impact on society. The presentation will also focus on the artistic competency that civil engineers have. The presentation will also reveal mobile artistic structures that different engineers have built. They will also learn about how knowledge of forces and energy transfer helps engineers build more secure structures to ensure safety. The students will then be given a presentation about different fields and forces and how they impact engineers when building structures. They will also learn about kinetic energy and potential energy and how they can convert into each other. The students will be given quick demos to demonstrate the concept of forces and kinetic and potential energy conversion. The students will be given the task to build a mobile structure that reflects their personal story. They will have to draw a sketch of their structure and they will include the materials that they will use. They will use their sketch to build a prototype of their structure. The students will then discuss the forces acting on their structures as well as demonstrate how their structure can illustrate potential/kinetic energy conversion. The structure must also be put into motion to test its security. The students will then all share their experience from the workshop as well as discuss how they can make an impact community based on the knowledge gained from their workshop experience.
Industry Connection	Mobile landmarks are common around the world (i.e. The London Eye). They need to be secure in order to ensure the safety of the community's inhabitants. Civil engineers have the responsibility of building visually pleasing structures that also account for the safety factors necessary to ensure the safety of people surrounding those structures.

STEM Field	Computer Science
Social Relevance	In this digital world it is becoming easier and easier to impersonate someone else by stealing their information. Important data needs to be protected and verifiable.
Academic Knowledge	Mathematical Operations: use parentheses and brackets to evaluate expressions Numbers and Operations in Base Ten: fluently perform multiplication and division with multi-digit numbers
Grade Level	6th, 7th
Learning Objectives	Students will be able to apply their knowledge of numerical operations to evaluate expressions that encode and decode messages using basic ciphers. Students will be able to design their own variations on these ciphers. Students will examine the role of cybersecurity engineers in designing algorithms for encrypting data. Students will recognize the importance of designing secure encryption algorithms that cannot be solved by others.
Sample Activity	Ciphers, Codebreaking, and Codemaking: Teach students about the Caesar cipher. They can try using the Caesar cipher with a small key (maybe a number between 1 and 5) to encode messages, then attempt to decode the messages of others without knowing the key. Once they have successfully decoded some, explain how this algorithm for encrypting a message is not very secure even without the key and would take a computer no time at all to crack. Next, introduce the Affine cipher. Have students create encrypted messages again following the numerical operations of the algorithm with any key values they like. Have them briefly look at the encrypted message to find patterns as they did with the Caesar encryptions. When they are unable to find any, explain how this is more complicated to crack without the key values. Finally, encourage students to design their own simple ciphers. A single mathematical operation on the numbers corresponding to the letters in their message is enough for these ciphers. Have them challenge each other to decode their own encrypted messages. This makes the connection to being a cybersecurity engineer, designing algorithms that obscure their inner workings, unlike the Caesar cipher, to encode files and keep them safe.
Industry Connection	Passwords are used for all types of accounts in many parts of our lives, from social media to work and to even bank accounts. This information is extremely valuable to every individual who uses the internet, and as long as it exists online, it should be safe behind digital keys and authorizations. Cybersecurity engineers design systems and algorithms to protect this information so that no one can access the decrypted data.

STEM Field	Computer Science
Social Relevance	Computer generated animations are often necessary in videos and movies for entertainment and educational purposes.
Academic Knowledge	Geometry and the Coordinate Plane: understand how to plot points in the coordinate plane using the x and y axes and x, y coordinates
Grade Level	6th, 7th, 8th
Learning Objectives	Students will apply their knowledge of graphing in the coordinate plane to move and control sprites in Scratch. Students will be able to create an animation using Scratch. Students will be able to author simple executable scripts using drag-and-drop pieces with no variable or loops. Students will recognize the fact that computer scientists can use computer scripts to make virtual objects and characters move without having to draw the characters over and over one-at-time.
Sample Activity	Creating Animations Using Scratch: Begin by teaching students how to write scripts in Scratch. Introduce them to movement code blocks, costume/sprite changing code blocks, and other visual effects only. Explain how computers treat the top of the screen as y = 0, and down is the positive y direction. Then, the students can then create short animations in teams by combining the movement of objects around the coordinate plane with visual effects in a logical flow. The animations themselves can be comedic, tell a story, teach something, or more. Once the teams are happy with their animations, they should be shown to the whole group. This presentation serves as incentive to make something entertaining. Make the connection that a computer scientist could have similar tasks in real life, using code to animate shapes and images for a whole range of applications, from the UI in one's phone, to the next Disney movie.
Industry Connection	We encounter virtual animations all the time in everyday electronics like our phones and computers. User interfaces are often animated to make them more understandable and appealing. Most movies in theaters today use computer animation in some degree as well. Computer scientists use computer instructions to create the animations as they appear.

STEM Field	Electrical Engineering
Social Relevance	Electricity is needed to power various electronic devices such as battery powered remote controls, flashlights, and toys.
Academic Knowledge	Students should know what electrical conductivity is and what kinds of materials conduct electricity the best.
Grade Level	7th, 8th Grade
Learning Objectives	Students will be able to apply their previous knowledge of electrical conductivity to explain that electricity can be moved through a circuit with the use of wires because the wires are made of conductive materials (i.e. metal). Students will design their own circuits to connect how electrical engineers are involved in designing circuits to power certain devices. Students will be able to apply their knowledge of new knowledge of electrical circuitry to identify typical items in a circuit and their contribution to the overall function of a device. (battery, switch, wire, buzzer, and light bulb) Students will be able to create their own toy with the basic knowledge of how a circuit works.
Sample Activity	Students will first be given basic instructions about how an electrical circuit is formed. They will be asked what they think a battery, buzzer, and switch does in a circuit. They will be asked questions including what a wire is and what is it probably made out of? They will also be asked what aluminum foil can do and what it's purpose could be in a circuit. This will connect their knowledge of electrical conductivity to the new knowledge about electrical circuits. Activity: Dance pad mania Students will first build their own buzzer circuit consisting of a battery, aluminum foil, a buzzer, and cardboard. They will have to decide how to make a switch that can turn the buzzer on and off. Other than being given these materials they will have to come up with their own design. The challenge is to create a design such that the buzzer can be hidden and activated by surprise. Students will discuss the elements of a circuit but this time being prompted to answer questions instead of being given information. They will also be asked to talk about their designs and what issues they may of had and why those issues occurred. Students are then put into teams of 3 and challenged to create a dance pad. The specification for this is that the design has to hold up to people constantly stepping on it. The circuit elements include wires, aluminum foil, a switch, a light, cardboard, etc. The design is completely up to their discretion. Then it's time to test their design. Groups are combined together and students play with their dance pads. If the pad breaks they must fix it.
Industry Connection	Electrical engineers work to try to allow everyone to have access to electricity no matter where they live and that power is delivered to houses in an efficient manner. They also work to develop ways to power our electronics and make sure they are safe to use.

STEM Field	Industrial Engineering
Social Relevance	Waiting time in restaurants is a frustrating experience most people endure on a regular basis.
Academic Knowledge	Number and Operations in Base Ten: Compute fluently with multi digit numbers Ratios and Proportional Relationships: Compute unit rates associated with ratios of fractions Statistics and Probability: Develop a probability model (which may not be uniform) by observing frequencies in data generated from a chance process.
Grade Level	7th Grade, 8th Grade
Learning Objectives	Students will apply IE concepts of lead time (the total time of a process), and takt time (maximum amount of time a product takes to be built to satisfy customer demand) Students will investigate the importance of workplace organization (5S: Sort, Set in Order, Shine, Standardize, Sustain) and its role in decreasing lead time and improving quality. Students will utilize their computational knowledge to add up the time it takes to perform steps in the process to calculate lead time. They will also use their knowledge of ratios to calculate takt time (available time in the day/customer demand). They will also develop probability models by observing frequencies of defects.

Sample Activity	Students will be introduced with information regarding what industrial engineers do, the industries that they are a part of, as well as information about the daily tasks they perform. They will also be presented with information about how industrial engineers time processes, improve quality, and have to efficiently allocate resources. They will also be introduced with technical terms such as lead time (the total time of a process), and takt time (maximum amount of time a product takes to be built to satisfy customer demand), (5S: Sort, Set in Order, Shine, Standardize, Sustain). They will also learn how to calculate takt time. Ice Cream Shop Simulation: Students will be split into customers, shop workers, inspectors and timers. The students will set up a mock ice cream shop. They will organize their materials and products. Students will be sitting down and periodically going up to stand in line as customers and they will be served by their peers. The servers will have a time that they have to serve the customers in and they have to keep up or else the order will be counted as defective. There will be inspectors counting the number of defective ice cream cones (the ones that are not compliant with the customer's order). There will also be students counting how many people go up to stand in line every minute and record that data. The students will then calculate the takt time based on how much time they have available and the customer demand data that was previously recorded. The students will also build a probability model for the defect data. Students will redo the simulation with IE principles they learned. They will write down a process (with multiple steps) that they should follow. They will also use 5S to organize the work station. A timer will time how much time each step in the process takes and compute a sum for total process time. The inspector will keep track of the amount of defected orders (this includes the orders that don't get completed within the takt time). The inspector will record the number of defects. The students will build a probability model for the frequency of defects of the second trial. The students will compare the probability models from the two trials as well as the two lead times. They will reflect on how 5S improved their lead time and number of defects. The students will then all share their experience from the workshop as well as discuss how they can make an impact in the real world based on their learning in the workshop.
Industry Connection	Industrial engineers have the knowledge and expertise to develop processes that improve our quality of life by reducing our wait time.

STEM Field	Industrial Engineering
Social Relevance	Many patients have long visits that can be much shorter, allowing other people to get treatment faster, reducing medical waitlists.
Academic Knowledge	Number and Operations in Base Ten: Compute fluently with multi digit numbers Ratios and Proportional Relationships: Compute unit rates associated with ratios of fractions
Grade Level	7th Grade
Learning Objectives	Students will apply of IE concepts of lead time (the total time of a process), and takt time (maximum amount of time a product takes to be built to satisfy customer demand) Students will investigate the importance of workplace organization (5S: Sort, Set in Order, Shine, Standardize, Sustain) and its role in decreasing lead time and improving quality. They will also experiment with different types of work cell layouts (u-shape, straight line, snake). Students will discover how task balancing can improve lead time. Students will utilize their computational knowledge to add up the time it takes to perform steps in the process to calculate lead time. They will also use their knowledge of ratios to calculate takt time (available time in the day/customer demand).
Sample Activity	Students will be introduced with information regarding what industrial engineers do, the industries that they are a part of, as well as information about the daily tasks they perform. They will also be presented with information about how industrial engineers time processes, improve quality, and have to efficiently allocate resources. They will also be introduced with technical terms such as lead time (the total time of a process), and takt time (maximum amount of time a product takes to be built to satisfy customer demand), (5S: Sort, Set in Order, Shine, Standardize, Sustain). They will also learn how to calculate takt time. Finally, they will learn about different types of work cell layouts as well as task balancing. Hospital visit simulation: Students will be split into doctors, assistants, patients, timers, and observers. The materials will be randomly distributed. The doctors will prepare medical kits that they need to treat the patients. The doctors will perform medical tasks on the patients (i.e. physical). The assistants will work alongside the doctors when performing the medical task. The timers will time the process and record the data. The observers will count how many people enter the waiting room per minute. This data will be used to calculate takt time. The students will redo the simulation using the IE principles they learned. The assistants are going to prepare medical kits for the doctors to use prior to when he needs the kit for a patient, reducing the number of tasks the doctor has to perform. The assistant will also organize the medical supplies according to 5S. The medical devices that will be used will also be set up in a u-shape so that the doctor moves the patient in a u-shape for the treatment. The timers will time the process and record the data. Students will get an opportunity to reflect on how the second simulations process improvement strategies caused the lead time to be shorter and helped the team comply to the takt time. They will compare the two data sets as a part of their discussion. The students will then all share their experience from the workshop as well as discuss how they can make an impact in the real world based on their learning in the workshop.

Industry Connection	Wait time is applicable to many different industries such as clothing stores, supermarkets, and gas stations. These are places we all go to regularly and impact our lives. Industrial engineers have the knowledge and expertise to develop processes that improve our quality of life by reducing our wait time and in some cases save lives by reducing medical wait lists for treatment.

STEM Field	Mechanical Engineering
Social Relevance	Many people need prosthetics to function but do not have access to and cannot afford such services.
Academic Knowledge	Engineering Design: create visual representations of solutions to a design problem. Interpret and apply scale to visual representations
Grade Level	6th, 7th, 8th
Learning Objectives	Students will be able to formulate a visual solution to a given engineering problem that requires a 3D model. Students will be able to create a simple 3D model in SolidWorks and 3D print it. Students will recognize the applications of 3D printing and the role mechanical engineers typically have in designing and printing parts.
Sample Activity	SolidWorks and 3D Printing: Show students box-modeling techniques to create a model of their own in SolidWorks. Explain how engineers can use this to model parts for their projects, like prosthetics for people, as they will soon be printed into reality using this program. They are then posed an engineering problem: creating a model of an existing toy, like a top, legos, dolls, etc. It can be anything they come up with, as long as it follows this theme, so that they are small and can be printed easily. Have students first hand-draw their ideas for their model, then move into SolidWorks once they all have a plan. Help students create their models, and then help them send the files to the 3D printers to start printing them. Explain that this is the very same process mechanical engineers use to 3D print parts for their own designs for all sorts of projects, including prosthetics with various materials. The use of toys as the problem means that the students will have something fun to take home, and that they understand the humanistic value of 3D printers firsthand.
Industry Connection	3D printing provides a cheap solution to many problems beyond prosthetic devices for rehabilitation, including manufacturing products with many different materials, and prototyping new technologies to benefit the world in a relatively cheap process. A mechanical engineer would use 3D printing to create physical prototypes or parts for machines of their design.

STEM Field	Mechanical Engineering
Social Relevance	It can be unsafe and uncomfortable for people to work alongside robotic machinery in factories.
Academic Knowledge	Materials and Manufacturing: select appropriate material for the construction of a solution to a given task
Grade Level	7th, 8th
Learning Objectives	Students will be able to create a silicone mold. Students will examine why silicone is an ideal choice for soft robots. Students will be able to create an actuating gripper out of only soft parts. Students will recognize the role of a mechanical engineer in designing soft joints like the gripper to keep workers safe.
Sample Activity	Silicone Gripper: Students begin by making a mold for a cross-shaped gripper out of cardboard. Explain why silicone is the ideal material for this workshop (it's soft, cheap, easy to make a mold for, and most importantly flexible). They then fill the mold partially with uncured silicone and let it cure. Then, using a cross-shaped piece of acetate that will define the pneumatic channel, they fill the rest of the mold with uncured silicone around the acetate piece. A piece of fabric is added to the very top before the silicone cures so that it all freezes together. This produces a gripper with a hollow core, and the fabric prevents the fingers from bending in the wrong direction. By attaching a syringe of fluid that connects the channel inside the gripper, the students can actuate the gripper by inflating the silicone. From here the finished soft grippers can be used in a crane game, moving objects using only the gripper. Explain the connection to the matching real-world functions, in which a mechanical engineer would use similar materials to design soft joints like this to pick up pieces in an assembly line.
Industry Connection	Soft robotics has applications in robotic surgery, as the soft pieces are viewed as less invasive. It also creates robots that are more flexible and adaptable, and therefore provide more functionality wherever they are deployed. Mechanical engineers work with all sorts of different materials depending on the situation to create mechanisms for specific solutions, like this soft gripper.

STEM Field	Physics
Social Relevance	Everyday electronic devices like cell phones require speakers to operate and be accessible to people with certain disabilities.
Academic Knowledge	Waves: waves have amplitude, frequency, and wavelength. Mechanical waves can be reflected, absorbed, or transmitted through various materials. Waves can be used to send information.
Grade Level	7th
Learning Objectives	Students will apply their knowledge of mechanical waves to analyze sound created by a speaker. Students will construct a speaker from scratch. Students will examine the way electromagnets behave and how they are used to transfer audio information through electricity. Students will be able to describe the role of a physicist in designing a speaker.
Sample Activity	Constructing a Speaker: Begin by teaching students about audio signals and electric fields in wires and in coils. The electricity in the aux cable connected to a phone is simply the same waveform that moves through the air when made into a sound wave. Students then receive materials for making their own speakers from scratch. They should use a coil connected to an aux cable, a magnet, and a cup (to amplify the sound) in their design. They should understand that the current in the coil creates a field that moves and vibrates the magnet ever so slightly, converting the electric waveform into a mechanical one. The vibrations of the magnet can vibrate the cup and the air which travels to their ear in the form of sound. Have students test their designs by connecting their phone and playing music. Explain that physicists work with these same pieces to design speakers.
Industry Connection	Engineers with backgrounds in physics use the same principles to design speakers and microphones for all sorts of applications like electric megaphones, PA systems, and any other electronic device that produces sound. Speakers and microphones help us connect with others around the world through telephones and broadcasts.

STEM Field	Robotics
Social Relevance	Assembly lines that work with dangerous chemicals or heavy machinery could use a robotic arm to transfer material as opposed to human workers to reduce the risk of injury.
Academic Knowledge	Technology/engineering: Engineering Design, Materials, Tools, and Manufacturing. Students should be aware of manufacturing processes, division of work, and flow within a factory.
Grade Level	6th Grade
Learning Objectives	Students will analyze how a robot can assist humans in various scenarios, including manufacturing. Students will apply their knowledge of materials and design to create a functional and dynamic tool given rigid objects, adhesives, and elastics or gears. They will also analyze how combinations of parts can translate to movement. Students will evaluate the usefulness of their creations in relationship to real world applications. Students will also analyze how they can improve their creations to better mimic creations by robotics engineers.
Sample Activity	Familiarize students with a few machines that help manufacturing processes. This can be video format or a live demonstration. Show how certain jobs can be dangerous to humans but safe for robots. This can be a Q&A followed by examples. Paint the activity scenario for the students. They will be creating a hand-operated robotic arm and grabber in order to pick up and transfer material. Students must create the arm out of legos and/or other supplies (e.g. straws, cardboard, rubber bands, and tape). The material being transferred can be play dough or putty to simulate toxic goo. With a few volunteer creations, demonstrate the parallels between the students' creations with robots being used currently. The rubber band equates to hydraulics, etc. Ask students what other applications their robots might be useful for and explain some examples of other uses.
Industry Connection	Much of our modern world relies on automation and machinery to perform dangerous and unsanitary tasks that are essential to a higher quality of life. Robotics engineers create machinery that can do risky tasks and operate at higher efficiency than humans. These engineers utilize biological functions such as bodily movement which uses bones, muscles, and nerves to inspire machinery that incorporates similar factors. A robot's "bones" are the rigid parts that give it structure, the "muscles" are the moveable parts that require energy, and the "nerves" are the electrical signals that tell the parts what to do.

8th Grade Modules

STEM Field	Biomedical Engineering
Social Relevance	Accidents as well as other medical conditions can leave a person physically disabled. They are then unable to perform tasks the same way as before and in some cases need assistance to do things tasks that we don't even think about such as holding a paintbrush.
Academic Knowledge	Students will understand how to take specifications for a device and both design and develop a working prototype.
Grade Level	6th, 7th, 8th
Learning Objectives	Students will value that assistive devices are needed by physically disabled people and they use them out of necessity and not out of choice. Students will be able to utilize the engineering design process to design a device having certain specifications due to how it will be used and who the user is.
Sample Activity	Students will be given an introductory overview of imagining themselves unable to use their hands and how that might affect their lives. They will then be introduced to the concept that engineers are able to design devices that can improve a person's quality of life. Students will then be challenged to use the engineering design process in teams to develop a device with certain criteria. This being lightweight, inexpensive, safe, durable, able to attach to hand or wrist, and able to hold a small paint brush or drawing instrument. They will then be given a list of available materials. They will generate an idea of a design, prepare a list of materials, construct a prototype, and test and evaluate their device. Possible redesign might have to happen based on user feedback. The last portion of this activity will focus on having the campers share their designs and the process they went through to get to their final design.
Industry Connection	Biomedical engineers are able to give physically disabled people the ability to continue living normal lives and to continue doing their passions. They blend together their knowledge about the human body with things such as mechanical engineering in order to create the perfect device that suits the need of the individual.

STEM Field	Biomedical Engineering
Social Relevance	When repairing broken bones some doctors need devices that are able to aid in the healing of these bones correctly and to not limit mobility of the person having to wear these fixtures.
Academic Knowledge	Students should know what bones are in the body and their main purpose.
Grade Level	6th, 7th, 8th
Learning Objectives	Students will be able to explain that bones are both strong and flexible which is why it's hard to repair or mimic their function perfectly. Students will be able to explain that the materials for bone fixing needs to be made of specific material such as stainless steel, titanium alloys, and polymers. Students will be able to explain that biomedical engineers aid doctors when a break needs to be able to restore function, likely to not heal correctly, high risk of infection, and long healing time. Students will use the engineering process to create prototypes that are able to repair a broken bone.
Sample Activity	Students will be given a presentation where the properties of bones are discussed. They will also be asked what materials they think are best used to recreate the function of bones and why this is. Materials: Femur bones (turkey), Screwdriver, Screws, Rods, Plates Students are given femur bones (turkey) and then they are broken using weights and the amount of weight that caused the bone break is recorded. They are then given a list of material they can use to fix the bone and are tasked with prototyping possible ways to repair the broken bones This will include drawing the design out with accurate scaling. They will then try to repair the bones using given materials and following their design. Design changes can be made throughout the process but must be justified. Then the bones are tested once again to see if they can hold up to the same weight or more. (this is a long project and probably would be better implemented in 7th grade or 6th grade.)
Industry Connection	Serious medical emergencies happen every day to people. This can be a failing organ, bodily functions that are not operating properly, etc. Biomedical engineers are able to aid in these types of emergencies and are currently trying to develop devices that can replace the function of an organ. Or other devices that are able to go into the human body to either help it function normally or replace it.

STEM Field	Biomedical Engineering
Social Relevance	People often take pills to help them get better. The coating on these pills are vital in ensuring that medicine is not exposed to stomach acid which can cause it to become unstable because of various chemical properties. Other times pills must be released at specific parts in our digestive system tract to ensure it will work as it is intended.
Academic Knowledge	Students should have basic understanding of the digestive system and its purpose in the human body.
Grade Level	6th, 7th, 8th
Learning Objectives	Students will examine why people take medicine and how important it is to people who are ill. Students will analyze the digestive system and be able to identify where stomach acid may cause an issue and what primary areas of the digestive system medicine should be released. Students will be able to identify the main reasons why pills need to have a coating on them: easier to swallow, preventing medicine from being released too quickly, preventing medicine from being released in an environment where it could be unstable. Students will be able to develop their own coating and see how mixing different combinations of dry and wet ingredients can create a better or worse pill coating.
Sample Activity	A patient with a sensitive stomach needs you to design a pill coating to prevent the medicine from being released into her stomach. Students will design a mock pill coating that must not dissolve in soda. The activity will start with an overview of the importance of medicine taken in the form of pills both for non-severe medical conditions as well as severe ones. A brief overview of the digestive system will be given, highlighting the different acidic levels. Students will be taught that acid is able to dissolve pill coatings faster causing the medicine to be released faster. The last slide should give the reasons why pills are coated. They will be given common household ingredients to mix together. This should include a mix of dry and wet ingredients such as olive oil, flour, corn starch, sugar, etc. They will then mix these ingredients to develop three different coatings. Throughout this mixing process they will write down and keep track of how much of each ingredient they used. They will then coat a candies with a dyed outside layer (skittles, M&Ms, etc.) with their pill coatings and put them into three different cups each with a type of soda in them. Wait for 10 minutes and then see if the candy has lost its coating or not.
Industry Connection	How medicine is delivered into our system is just as vital as the medicine itself. Without taking careful consideration to how medicine is delivered can cause it to be ineffective or even harmful to the human body. Biomedical engineers are able to use both chemistry as well as their knowledge of the human body to develop devices and things that must work with the chemicals that our body produces.

STEM Field	Chemical Engineering
Social Relevance	Air pollution depletes the Ozone Layer and causes global warming. A warmer globe means melting ice caps which leads to rising sea levels. This could cause coastal structures and islands to drown in the ocean. Currently, there is a lack of renewable energy methods to mitigate this issue.
Academic Knowledge	Physical Science Energy: • Apply scientific principles of energy and heat transfer to design, construct, and test a device to minimize or maximize thermal energy transfer • Conduct an investigation to determine the relationships among the energy transferred, how well the type of matter retains or radiates heat, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. Technology and Engineering: • Construct a prototype of a solution to a given design problem
Grade Level	8th Grade
Learning Objectives	The students will relate chemical engineering to developing renewable energy methods. The students will use their understanding of energy transfer and their experience with building prototypes to build a device that converts energy. Students will visualize how building this prototype stimulates the role that they can have as a chemical engineer in the real world.
Sample Activity	Students will be given a presentation about chemical engineers, their tasks, and their impact on society. They will also be presented with information about the need for renewable energy and the role of chemical engineers in developing renewable energy methods. The students will then learn about fundamentals about energy transfer. Students will be instructed to make a device of berry dye and is used to convert solar energy into electrical energy. Students will be split into teams and each team will have the help of an instructor. The instructor will demonstrate the process, and the students will have to chance to imitate the process. More info regarding this activity can be found on this site: https://www.teachengineering.org/activities/view/uoh_organic_activity1
Industry Connection	Chemical engineers can have a big impact on society as they can develop alternative renewable energy methods that can help with air pollution.

STEM Field	Chemical Engineering
Social Relevance	We use many different products in our everyday lives that can be very expensive. People have to oftentimes compromise quality for lower prices when purchasing these necessary products. However, people are often unaware of the processes to make homemade quality products at a lower cost.
Academic Knowledge	Life Science: Use informational text to describe that food molecules, including carbohydrates, proteins, and fats, are broken down and rearranged through chemical reactions forming new molecules that support cell growth and/or release of energy.
Grade Level	8th Grade
Learning Objectives	The students will relate chemical engineering to developing household products. Students will apply their understanding of chemical reactions and enzymes to develop a household product. They will have the opportunity to visualize how they have the power of making a household product like chemical engineers in the industry.
Sample Activity	Students will be given a presentation about chemical engineers, their tasks, and their impact on society. They will also be presented with base knowledge that they need to know about chemical reactions and enzymes. Students will make homemade detergent and have one sample with enzymes and one without. Students will test the effectiveness of both detergents on soiled fabric and compare the differences. For more details on the activity: https://www.thespruce.com/laundry-detergent-comparison-science-project-2146205 https://www.smallfootprintfamily.com/homemade-laundry-detergent-recipe Students will reflect on the results and use scientific language (i.e. the function of enzymes) to describe the phenomenon they encountered. Students will also reflect as a group about what they learned from the workshop as well as how their knowledge can be applied to their household, and the community as a whole.
Industry Connection	Chemical engineers have the ability to develop cost effective solutions without compromising quality.

STEM Field	Civil Engineering
Social Relevance	Weather conditions and natural disasters such as hurricanes and blizzards often damage or destroy homes.
Academic Knowledge	Technology and Engineering: • Materials, Tools, and Processes: Present information that illustrates how a product can be created using basic processes in manufacturing systems, including forming, separating, conditioning, assembling, finishing, quality control, and safety • Construct a prototype of a solution to a given design problem • Given a design task, select appropriate materials based on specific properties needed in the construction of a solution
Grade Level	8th Grade
Learning Objectives	Students will investigate the relevance of their designs and the effect that they can have on a community. Students will learn and apply civil engineering terminology such loading, tension, compression, span, support, joint, connection, abutment, footing. They will be able to practice using that terminology as well as the civil engineering design process when building a prototype. They will design structures that account for several restraints (i.e. space and weather conditions). Students will design structures that maximize volumetric space with scarce materials as well as handle max loads in case of harsh weather conditions. Students will visualize how building this prototype stimulates the role that they can have as a civil engineer in the real world.
Sample Activity	Students will be given a presentation about civil engineers, their tasks, and their impact on society. They will also be taught civil engineering terminology (loading, tension, compression, span, support, joint, connection, abutment, footing) as well as the civil engineering design process (Define the Problem, Do Background Research, Specify Requirements, Brainstorm Solutions, Choose the Best Solution, Do Development Work, Build a Prototype, Test and Redesign). Students will be given the problem of designing a building that they can build using K'NEX that would be beneficial in a rural community. Designs must comply with space specifications and survive different weather patterns such as strong winds or cold weather. Students will follow the design process to build their prototype. They will document their journey following the design process and they will share that with the rest of their peers. The students will then all share their experience from the workshop as well as discuss how they can make an impact community based on the knowledge gained from their workshop experience.
Industry Connection	Structures must be built with the regional climate in mind in order to withstand harsh conditions and keep people safe. Civil engineers have the ability to build cost effective structures that can endure harsh weather patterns that are common in many communities around the world.

STEM Field	Computer Science
Social Relevance	Computer generated animations are often necessary in videos and movies for entertainment and educational purposes.
Academic Knowledge	Geometry and the Coordinate Plane: understand how to plot points in the coordinate plane using the x and y axes and x, y coordinates
Grade Level	6th, 7th, 8th
Learning Objectives	Students will apply their knowledge of graphing in the coordinate plane to move and control sprites in Scratch. Students will be able to create an animation using Scratch. Students will be able to author simple executable scripts using drag-and-drop pieces with no variable or loops. Students will recognize the fact that computer scientists can use computer scripts to make virtual objects and characters move without having to draw the characters over and over one-at-time.
Sample Activity	Creating Animations Using Scratch: Begin by teaching students how to write scripts in Scratch. Introduce them to movement code blocks, costume/sprite changing code blocks, and other visual effects only. Explain how computers treat the top of the screen as y = 0, and down is the positive y direction. Then, the students can then create short animations in teams by combining the movement of objects around the coordinate plane with visual effects in a logical flow. The animations themselves can be comedic, tell a story, teach something, or more. Once the teams are happy with their animations, they should be shown to the whole group. This presentation serves as incentive to make something entertaining. Make the connection that a computer scientist could have similar tasks in real life, using code to animate shapes and images for a whole range of applications, from the UI in one's phone, to the next Disney movie.
Industry Connection	We encounter virtual animations all the time in everyday electronics like our phones and computers. User interfaces are often animated to make them more understandable and appealing. Most movies in theaters today use computer animation in some degree as well. Computer scientists use computer instructions to create the animations as they appear.

STEM Field	Electrical Engineering
Social Relevance	Electricity is needed to power various electronic devices such as battery powered remote controls, flashlights, and toys.
Academic Knowledge	Students should know what electrical conductivity is and what kinds of materials conduct electricity the best.
Grade Level	7th, 8th Grade
Learning Objectives	Students will be able to apply their previous knowledge of electrical conductivity to explain that electricity can be moved through a circuit with the use of wires because the wires are made of conductive materials (i.e. metal). Students will design their own circuits to connect how electrical engineers are involved in designing circuits to power certain devices. Students will be able to apply their knowledge of new knowledge of electrical circuitry to identify typical items in a circuit and their contribution to the overall function of a device. (battery, switch, wire, buzzer, and light bulb) Students will be able to create their own toy with the basic knowledge of how a circuit works.
Sample Activity	Students will first be given basic instructions about how an electrical circuit is formed. They will be asked what they think a battery, buzzer, and switch does in a circuit. They will be asked questions including what a wire is and what is it probably made out of? They will also be asked what aluminum foil can do and what it's purpose could be in a circuit. This will connect their knowledge of electrical conductivity to the new knowledge about electrical circuits. Activity: Dance pad mania Students will first build their own buzzer circuit consisting of a battery, aluminum foil, a buzzer, and cardboard. They will have to decide how to make a switch that can turn the buzzer on and off. Other than being given these materials they will have to come up with their own design. The challenge is to create a design such that the buzzer can be hidden and activated by surprise. Students will discuss the elements of a circuit but this time being prompted to answer questions instead of being given information. They will also be asked to talk about their designs and what issues they may have had and why those issues occurred. Students are then put into teams of 3 and challenged to create a dance pad. The specification for this is that the design has to hold up to people constantly stepping on it. The circuit elements include wires, aluminum foil, a switch, a light, cardboard, etc. The design is completely up to their discretion. Then it's time to test their design. Groups are combined together and students play with their dance pads. If the pad breaks they must fix it.
Industry Connection	Electrical engineers work to try to allow everyone to have access to electricity no matter where they live and that power is delivered to houses in an efficient manner. They also work to develop ways to power our electronics and make sure they are safe to use.

STEM Field	Game Development
Social Relevance	There are many moments in our day that we could use a short and simple game to pass the time. These games preferably do not have extensive backstories or long gameplay that requires multiple saves and play sessions.
Academic Knowledge	Programming: Awareness of basic concept of code and how it creates a running program
Grade Level	8th Grade
Learning Objectives	Students will visualize how game developers can create a simple but sophisticated game. This can be more difficult than creating a game with deep backstory and complicated mechanics because the developers must express those ideas concisely. Students will be able to create a simple video game given the rules of the game and necessary programming functions. They will analyze how their code translates to a running game. Students will visualize the workflow of a game programmer through their own trial and error while creating their game.
Sample Activity	Program a game of Pong given the necessary functions and variables. Students will piece the functions together like puzzle pieces and test the game as they go.
Industry Connection	Video games can be used to pass time and stimulate the brain, meaning the player is learning. These games are useful for teaching kids because it keeps them engaged and for adults to maintain an active brain. Game developers invent mechanics and methods to help people pass time, to teach concepts, and to think further about a subject while being entertained and immersed.

STEM Field	Mechanical Engineering
Social Relevance	It can be unsafe and uncomfortable for people to work alongside robotic machinery in factories.
Academic Knowledge	Materials and Manufacturing: select appropriate material for the construction of a solution to a given task
Grade Level	7th, 8th
Learning Objectives	Students will be able to create a silicone mold. Students will examine why silicone is an ideal choice for soft robots. Students will be able to create an actuating gripper out of only soft parts. Students will recognize the role of a mechanical engineer in designing soft joints like the gripper to keep workers safe.
Sample Activity	Silicone Gripper: Students begin by making a mold for a cross-shaped gripper out of cardboard. Explain why silicone is the ideal material for this workshop (it's soft, cheap, easy to make a mold for, and most importantly flexible). They then fill the mold partially with uncured silicone and let it cure. Then, using a cross-shaped piece of acetate that will define the pneumatic channel, they fill the rest of the mold with uncured silicone around the acetate piece. A piece of fabric is added to the very top before the silicone cures so that it all freezes together. This produces a gripper with a hollow core, and the fabric prevents the fingers from bending in the wrong direction. By attaching a syringe of fluid that connects the channel inside the gripper, the students can actuate the gripper by inflating the silicone. From here the finished soft grippers can be used in a crane game, moving objects using only the gripper. Explain the connection to the matching real-world functions, in which a mechanical engineer would use similar materials to design soft joints like this to pick up pieces in an assembly line.
Industry Connection	Soft robotics has applications in robotic surgery, as the soft pieces are viewed as less invasive. It also creates robots that are more flexible and adaptable, and therefore provide more functionality wherever they are deployed. Mechanical engineers work with all sorts of different materials depending on the situation to create mechanisms for specific solutions, like this soft gripper.

STEM Field	Mechanical Engineering
Social Relevance	Roller coasters must be designed in such a way that they are both safe and entertaining for their passengers.
Academic Knowledge	Physics: describe the relationships among kinetic energy, mass, and speed of an object. Describe the relationships between relative positions of objects and their relative potential energies.
Grade Level	8th
Learning Objectives	Students will be able to design a roller coaster by applying their knowledge of energy conservation principles and kinetic/potential energy of objects in a system. Students will formulate a design for a roller coaster that keeps the cost of its parts within the limits of a specified problem and budget. Students will evaluate roller coaster designs for their aesthetic appeal and test them for safety. Students will be able to describe the role of mechanical engineers in designing solutions within the limitations and budget provided to them.
Sample Activity	Past CR activity: Roller Coaster Provide students with the challenge: to design a roller coaster ride that maximizes the ratio of loop diameter to material cost. The coaster should also be aesthetically pleasing and, obviously, safe. The students will understand how conservation of energy would keep loops at the same height every time if the car were not losing energy. Explain how friction removes energy from the system, so, by the laws of conservation of energy, the roller coaster will not have enough energy to reach a loop as high as the previous one, and loops in fact will be progressively getting lower as the track goes on. Once the students have come up with designs by hand, have them purchase the parts they need from a simulated store. This introduces a limiting factor of cost in the decision-making and optimization undertaken by the students. Finally, students can build and test their own designs, and they can rate each other's rides on looks and aesthetics. The roller coasters are scored in a final analysis phase of the workshop (loop amount/$spent + aesthetic points). Students get the opportunity to iteratively modify the tracks. Explain how this is the same as a problem handed to a mechanical engineer, in that they must first draw up a potential design, find the price to build it, and then build and test the design.
Industry Connection	Energy balance equations are used in many different things created by mechanical engineers, from the thermal and electrical energy in a refrigerator to the potential and kinetic energy of a swingset. Engineers in this field use these same methods when calculating and sizing up their machines.

STEM Field	Mechanical Engineering
Social Relevance	Many people need prosthetics to function but do not have access to and cannot afford such services.
Academic Knowledge	Engineering Design: create visual representations of solutions to a design problem. Interpret and apply scale to visual representations
Grade Level	6th, 7th, 8th
Learning Objectives	Students will be able to formulate a visual solution to a given engineering problem that requires a 3D model. Students will be able to create a simple 3D model in SolidWorks and 3D print it. Students will recognize the applications of 3D printing and the role mechanical engineers typically have in designing and printing parts.
Sample Activity	SolidWorks and 3D Printing: Show students box-modeling techniques to create a model of their own in SolidWorks. Explain how engineers can use this to model parts for their projects, like prosthetics for people, as they will soon be printed into reality using this program. They are then posed an engineering problem: creating a model of an existing toy, like a top, Legos, dolls, etc. It can be anything they come up with, as long as it follows this theme, so that they are small and can be printed easily. Have students first hand-draw their ideas for their model, then move into SolidWorks once they all have a plan. Help students create their models, and then help them send the files to the 3D printers to start printing them. Explain that this is the very same process mechanical engineers use to 3D print parts for their own designs for all sorts of projects, including prosthetics with various materials. The use of toys as the problem means that the students will have something fun to take home, and that they understand the humanistic value of 3D printers firsthand.
Industry Connection	3D printing provides a cheap solution to many problems beyond prosthetic devices for rehabilitation, including manufacturing products with many different materials, and prototyping new technologies to benefit the world in a relatively cheap process. A mechanical engineer would use 3D printing to create physical prototypes or parts for machines of their design.

STEM Field	Physics
Social Relevance	People are injured all the time in car crashes, so car manufacturers must implement safety precautions to prevent harm to people.
Academic Knowledge	Physical Sciences: describe the relationships among kinetic energy, mass, and speed of an object. Describe the relationships between relative positions of objects and their relative potential energies.
Grade Level	8th
Learning Objectives	Students will apply their knowledge of energy to discover the change in momentum of the crashing car. Students will be able to construct a solution that reduces impulse during a collision to keep passengers safe. Students will recognize the role of physics in the design of car safety features.
Sample Activity	Egg Car Crash: Introduce students to collisions and impulse. Set up a ramp on which to drop cars such that they accelerate and crash into a wall at the bottom. Give students materials to build a little car that houses an egg. The challenge is to crash the car with a momentum of at least 7 kg*m/s. The egg can be placed in a container that surrounds it with nails to increase the difficulty of the problem. Have the students use conservation of energy and the impulse-momentum formula to find the specifications for their car (specifically the mass it should have to achieve or exceed the correct momentum). They must protect the egg during the collision using only the car itself, most likely by increasing the time the impulse takes by using cushioning. Let students flex their creativity and discover for themselves what methods work to reduce the force of the impulse and save the egg. Explain how people with a physics background would use a similar method when designing and testing crashes with real cars that must protect their passengers.
Industry Connection	Engineers with backgrounds in physics use the same principles in designing padding to keep people safe while playing various sports, shoe soles to keep people's feet comfortable, and even bullet-proof vests to keep people alive in combat.