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Teaching STEM to K-12 Students: Undergraduate Students Engaged in Engineering Pedagogical Development in a COVID-Persistent Learning Environment

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Abstract

Knowledge of science and engineering plays a major role in solving problems and enhancing people's lives in our world today. Investing in the future's science, technology, engineering, and math (STEM) professionals is vital to strengthening the growing demand for engineers. Previous studies about raising interest in STEM majors focused on (a) the number of undergraduate students who decide on a major prior to attending college, (b) common misconceptions regarding the STEM field, and (c) the effectiveness of pedagogical techniques to increase curiosity. However, during the COVID-19 pandemic, pedagogical techniques to introduce K-12 students to the STEM fields must be adjusted. This paper investigates the effectiveness of various methods to engage and interact with K-12 students interested in STEM during the COVID-19 learning environment and discusses key conclusions from a pilot 90-minute virtual module for K-12 students, showcasing the importance and versatility of STEM in the modern world. Through hands-on activities, interactive games, easy to use software, demonstrations, and videos, student interest and curiosity in the STEM field is increased and K-12 teachers are provided with tools to continue to foster this curiosity throughout the school year. Surveys were taken before and after the learning module measure interest in the STEM fields directly related to the module provided. Studies have shown that there is a positive correlation between motivational, secondary learning, and post-secondary variables on the desire to be a STEM student. Throughout our education system, many misconceptions cast the STEM field as tough and only designed for the smartest of students. Data from a U.S. news article shows that one-third of kids lose interest in this field prior to fourth grade, and 50% have lost interest by the eighth grade. These misconceptions lead students to become disinterested in a field of study for which they have only had a paltry exposure. Studies have shown that the best ways to spark curiosity in the STEM field is through hands-on activities, field trip tours, interactive games, and real-world applicability. The main reasons that educational institutions have trouble providing these concepts to their students is because of the lack of funding and the varying emphasis on STEM programs. There are numerous sites, sources, and programs expose students to STEM, which require minimal resources and funding in the eyes of the schools. The study found that capitalizing on the increased use of technology in the current COVID learning environment enables K-12 teachers to increase STEM awareness, interest, and intellectual curiosity of K-12 students in the virtual classroom. Further, the study found that connecting K-12 students with professionals across the STEM fields brings the virtual modules to life by connecting the learning to real-world applications and allowing students to "see themselves" in the field. Together, the teachers and professionals leverage the technology to draw a diverse group of young people to STEM fields in the future.

Introduction

The problem this paper will address is how to excite and inspire K-12 students to major in the STEM field in a virtual environment. COVID-19 has reshaped the world's education systems and the role technology plays in teaching young students. This study investigates the effectiveness of various methods to engage and interact with K-12 students interested in STEM during the COVID-19 learning environment and discusses key conclusions from a pilot 90-

minute virtual module for K-12 students. This study will also give educators further insight into creating an effective virtual environment as well as providing various, useful tools to engage and develop students.

The narrative regarding STEM is often one that produces many defeatist and frightening thoughts and reactions leading individuals to shy away from participation in many STEM-related fields and activities. This narrative along with the lack of early STEM education leads to a wide array of misconceptions and rumors regarding STEM disciplines. According to an American Society for Engineering Education (ASEE) report from 2018, between 2013 and 2016, the total number of students who received bachelor's degrees in civil engineering declined by 8% in the U.S. [1]. This decrease creates some concerns because the U.S. Bureau of Labor Statistics (BLS) projects employment with nearly 140,000 new jobs expected for engineers over the 2016–26 decade, meaning in perspective, there will be a high demand for engineering graduates [2]. This staggering figure displays that the level of interest in the STEM field has declined substantially in recent years. Increasing the interest of students in the STEM field will present the growing need for engineers as a necessary change to sustain the increasing demand for infrastructure, houses, businesses, energy, water, and infrastructure.

In a 2008 report, a public high school authority in the U.S. discovered an extremely low level of interest for participating in STEM-related career academics in high school among middle school students; however, the students showed higher interests in arts, literatures, businesses, and entertainment-related careers, especially the females who make up only 25% of the STEM jobs [3], [4]. Recently, a 2018 research conducted on behalf of Junior Achievement and Ernst & Young LLP (EY) revealed a significant drop. Only 24% of boys were interested in a STEM career (down from 36% in 2017). Girls' interest remained unchanged at 11% [5]. If low enrollment in STEM fields and low interest in STEM academics continue, access to STEM-related jobs for U.S. graduates could potentially be at risk. The World Economic Forum reported that in 2016, the U.S. graduated 568,000 individuals from STEM fields compared to 4.7 million from China and 2.6 million from India [6].

Unfortunately, children in U.S. public school systems are met with generalized teachers who are forced to teach, essentially, every school subject. This generalization can lead to a lack of intellectual excitement and a mere recitation of basic facts. For children to truly understand the creativity and potential of STEM, they must receive knowledge and curricula with regards to STEM subjects from authorities in the field. Instead, for children exposed to STEM and who understand available career options, many are diverted simply with the thought of it being too hard. This misconception is by far the most common and most impactful with regards to the subject. Students believe that STEM majors and disciplines are math and time-intensive and are only accomplished by the strongest of students. This stereotype that people in STEM are technology-obsessed geniuses guides many to choose far easier career paths [7].

Literature Review

There is a growing divide between the availability and demand for STEM-specialists and engineers. According to an article published by the World Economic Forum in December 2019, the demand for talent in the infrastructure sector is growing, but there is a lack of STEM-specialists and engineers to meet this need [8]. Prior exposure to STEM activities appears to positively shape the STEM field of the future. A journal of Pre-college Engineering Education

Research by the University of Wisconsin showed that exposure to Engineering and Engineering Technology courses (E&ET) was associated with a substantially greater likelihood that students would choose to enter STEM college majors in a four-year institution [9]. Other ideas and activities that can spark young students' interests and enthusiasm in STEM careers include the following: organizing fundraising events with the community or other projects that increase budgeting and math skills; teaching youth at science summer camps or after-school programs; getting students to join math and science clubs; exploring technology hobbies like games among school children; helping them to participate in science like hands-on activities; basic computing and internet browsing; including them in internet forums and social networking; giving them books and magazines on science and mathematics; motivating them to pursue science and engineering careers; and helping them to learn about computer parts [10]. When infused with STEM lessons, these types of activities can both inspire and encourage those potentially interested in a STEM career to follow through with their desire. A 2006 study published in Science Magazine supports this strategy and found that children interested in STEM at an eighth-grade level are significantly more likely to pursue a STEM-related career in college than those who simply perform well on math and science tests [11]. These studies underscore the importance of exposure to innovation in early education, which sustains student engagement in STEM fields and makes related subjects more accessible for all students.

There is likely tremendous value in studying what constitutes effective teaching with inspired and engaged students at the college level. For over 20 years, the American Society for Civil Engineering (ASCE) Excellence in Civil Engineering Education (ExCEEd) Teaching Workshop has trained nearly 1,000 engineering faculty members at over 250 different U.S. and international colleges and universities on the principles of effective teaching [12]. The workshop focuses its seminars, demonstration classes, and practice classes around an ExCEEd Model consisting of:

1. Structured organization that is based on learning objectives, appropriate to the subject matter, and appeals to different learning styles.
2. An engaging presentation with clear communication, a high degree of contact with students, and physical models and demonstrations.
3. Enthusiasm!
4. Positive rapport with students.
5. Frequent assessment of student learning (both in and out of class).
6. Appropriate use of technology.

As shown in *Celebrating 20 Years of the ExCEEd Teaching Workshop* presented in June 2018 at 125th ASEE Annual Conference and Exposition, the effectiveness of the ASCE ExCEEd Model and Teaching Workshop has been repeatedly validated [12]. While the aforementioned studies and models are centered around in-person teaching and learning, there are opportunities to educate and inspire students in STEM during a pandemic with minimal resources and little preparation time, regardless of being virtual or in-person. Interactive virtual tours are just one example of a great way to provide early exposure to the field.

When looking at reaching K-12 students and teaching them more about STEM majors, it is important to consider how online teaching has been conducted in the past and its effects on the students. A study about best teaching practices in K-12 online performed in Michigan virtual school involving 16 highly qualified teachers showed that teachers must be willing to go the

extra mile to effectively engage students for an online lesson. They must modify their instructional practices and pedagogical techniques, be flexible, and have a deep understanding of different learning capabilities [13]. Along with this, it is important to broaden access in ways that provide different alternatives to have quality education other than the conventional face-face interaction. Students who struggle in a regular classroom will often struggle even more in an online environment [14]. Some major aspects that students struggle with when it comes to online learning include poor time management, lack of self-motivation, distractions, technical issues, and computer illiteracy. These virtual issues are huge, problematic factors that affect students across the board, regardless of the subject matter. However, given than many already perceive that STEM subjects are too hard to begin with make it even more difficult for teachers trying to educate and inspire students in a virtual environment. Taking all this into consideration, it is imperative for faculty to effectively plan an outreach that provides an environment for students to feel comfortable venturing into fields of studies which they do not feel comfortable with.

Building upon this current body of knowledge, our outreach plan sought to integrate necessary aspects of teaching that would be fun, engaging, interesting, captivating and easy to understand for the students while also offering a complex problem that challenged the students to think creatively and innovatively. Such a program can provide the framework for future remote learning experiences without sacrificing the ability to inspire students to push the boundaries of conventional thinking.

Methods

This study is grounded on both empirical and analytical evidence in order to reach a valid determination. The analysis in this paper begins with research and discussion of STEM importance, determining the interest level, and K-12 students perceptions of the field. Once these were determined, an elaborate plan for a physical workshop was made. This STEM workshop focused on exposing high school students to engineering in order to increase their curiosity and likelihood of choosing a STEM degree in the future. This STEM workshop was devoted to building curiosity among the students and increasing their likelihood to seek a future in the STEM field. This workshop proposed many challenges given the virtual environment. The students who attended the conference were a group of high school students from Franklin Military Academy in Richmond, VA. Due to the COVID-19 restrictions put in place, the workshop was held completely virtually through Google Classroom.

This workshop was a conglomerate of ethics, diversity, and STEM discussions led by the Department of Civil and Mechanical Engineering as well as the Department of Social Sciences at the United States Military Academy, West Point. However, this paper will focus solely on the STEM portion of the workshop.

The first step for this workshop was to determine a simple, yet effective program for the time constraints and physical limitations in place. Based on information obtained from the literature review and recent experience from authors (as students and faculty members during COVID), the authors developed a 45-minute module broken into five blocks: Introduction of the Workshop Leaders, Building the Guard Tower, the 5 W's of Trusses in 5 Minutes, Testing and Lessons Learned, and a Check on Learning and Closeout of the module. The purpose of Block 1 was to quickly establish rapport with the students, provide an orientation to the STEM module, and lay out the objectives of the module. As shown in Figure 1, each student shared a brief personal

introduction to include why they chose civil engineering as their college major. While time was limited, the authors believed the personal introduction would help minimize potential anxiety, encourage participation, and even inspire some of the students to visualize themselves as a college STEM student. Although brief, the purpose of the orientation was to grab the attention and make a connection to the students by explaining to them why the STEM module was important and how what they were about to learn was connected to material they were already familiar with.

Fig 1. Building positive rapport with audience through personal introductions

The purpose of Block 2 was to generate enthusiasm and engagement into the STEM Module through a hands-on activity involving the construction of a guard tower out of K'NEX. Since the students and faculty members from Franklin Military Academy were at home while the STEM module presenters were on campus at West Point, NY, clear communication was extremely critical and required extra time and attention. First, as shown in Figure 2, the authors mailed 20 bags of K'NEX to the high school. Each bag had more than enough K'NEX to construct the tower according to the provided design criteria. Then, over multiple online meetings and rehearsals, the authors demonstrated how to use K'NEX to the high school faculty. This, in turn, allowed the high school faculty to demonstrate how to use the K'NEX to the high school students prior to the STEM module. Given the short time period allotted to design and build the tower, these virtual meetings were critical to ensure everyone was synchronized. To further assist with K'NEX familiarity prior to the STEM module, the authors provided the high school faculty

with a YouTube video to share with their students in order to demonstrate the fun and creativity that K'NEX offers.

Fig 2. K'NEX shipment for hands-on activity

Clear communication was also critical in the explanation of the design criteria and competition scenario. Thus, the authors provided the high school faculty with a one-page slide, shown in Figure 3, describing the requirements of this hands-on competition through written and visual communication prior to the STEM workshop. In addition, the authors provided this verbal description to the students during the Google Meets module: *"Due to a recent hurricane in the Richmond area, one of the security towers at Richmond International Airport was damaged. This tower must be replaced as soon as possible, and the US Army Corps of Engineers is the lead construction agency for the project. They are looking for the lowest cost tower (determined by the least number of K'NEX used) that can support the required guards and surveillance facility (two bricks) off the ground (minimum of 12-3/4 inches) to ensure the local area is secured. Each of your four teams from Franklin Military Academy will have an opportunity to design, build, and test your proposal to the US Army Corps of Engineers. Your proposal is due in 15 minutes."* It is also important to note that the authors intentionally used the Richmond International Airport and the US Army Corps of Engineers as part of the scenario. Given that the Richmond International Airport is within five miles of their high school, it is safe to assume all of the students had some previous connection with this airport. Inclusion of the US Army Corps of Engineers ties STEM with the Army and the authors personal stories. This intentionality, again, was designed to engage the students and develop rapport.

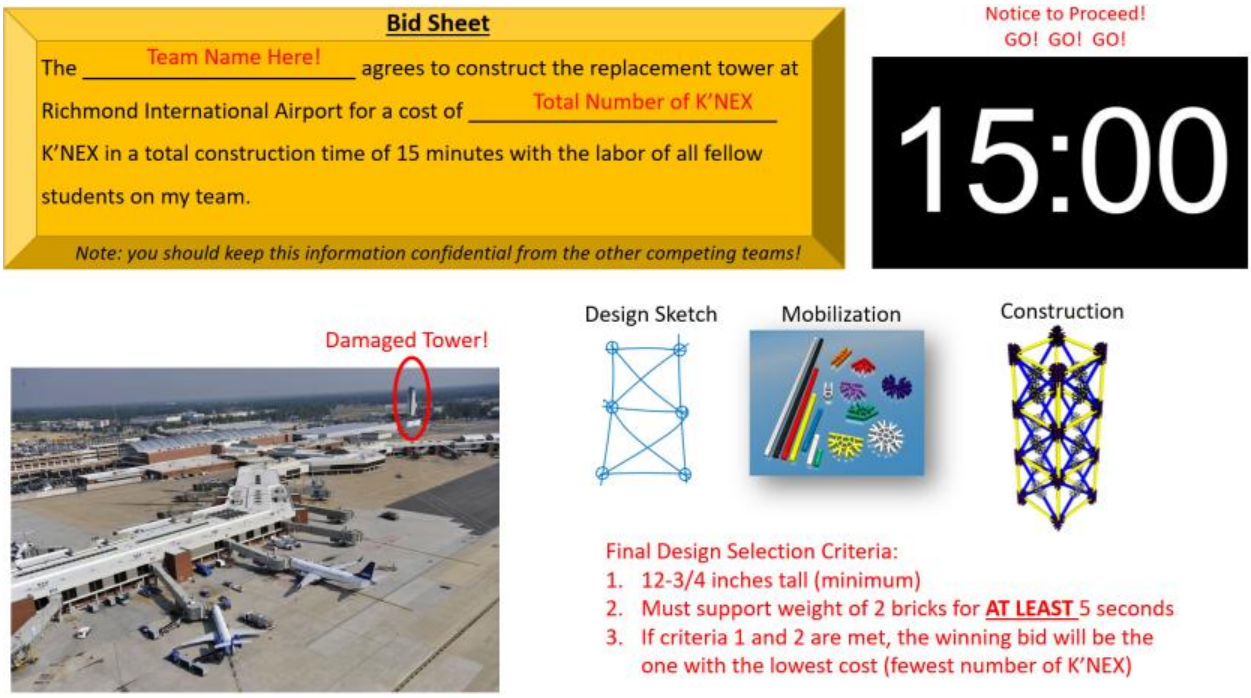

Fig 3. Scenario for STEM Module demonstrating clear communication

During the design and build process, each team was paired up with a Civil Engineering workshop leader to inspire and provide technical support along the way. Upon completion of providing guidance in the main virtual room, students, their high school faculty, and the civil engineering workshop leaders were sent to four different breakout rooms. In these groups, faculty and workshop leaders assisted and motivated the students to complete the tower in the given time constraint. Despite the preparatory work ahead of time, the 15-minute time constraint proved to be a challenge because many of the students had never used K'NEX before and struggled to understand how they work. After the 15-minute construction period was over, the students were transferred back to the main virtual classroom.

Block 3 of the STEM module was entitled, "The 5 W's of Trusses in 5 Minutes." This portion was focused on teaching the students about what trusses are, why they work, the importance of bracing, and the basics of tension and compression members within a structure. In short, the authors were attempting to give five hours of sophomore-level college engineering in five minutes over a virtual platform! Success, measured through student learning, demanded enthusiasm and physical models and demonstrations. Furthermore, this block was intentionally scheduled to occur after the design and construction block, as some students learned lessons through both success and failure from their 15-minute build. There were a total of three different demonstrations used in order to reinforce the material being instructed. The first demonstration consisted of a pool noodle to demonstrate the tension and compression element within a given member. As the pool noodle was pulled, the deformation and stretching allowed the authors to explain the tension limit states of yielding and rupture. On the contrary, as shown in Figure 4, when the pool noodle was pushed from both ends, it easily buckled, which portrays the vast difference between the tension and compression limit states. This compression demonstration closely related to the hands-on activity because most of the guard tower K'NEX pieces were in compression.

Fig 4. Demonstrating tension and compression member using a pool noodle

Given the abundance of compression members in the towers, a significant amount of bracing is required to prevent the long and slender members from buckling. Thus, the authors used a physical model, shown in Figure 5, to demonstrate the impact bracing has on the compressive strength of a member. As shown, a long, skinny, plastic column was set in a wood box providing pinned support conditions for the column. A wooden block on top of the column enabled the authors to apply a load to the column. With the load applied, the unbraced column easily buckled under little weight. Then, a piece of bracing was placed at the midspan of the member, and the column no longer buckled under the applied load. With the unbraced length cut in half, Euler's buckling equation states that it takes four times the load in order to make the column buckle. Applying this math and science through a physical model and demonstration allowed the authors to effectively engage their audience.

Fig 5. Effective length demonstration to a virtual audience

The final demonstration for “The 5 W’s of Trusses in 5 Minutes” was centered around the strength and stability gained when using a triangular geometry. The authors used a physical truss model with wood members and metallic nuts and bolts holding together the joints. When the pinned geometry did not have a triangular shape, as shown in Figure 6, the model lacked stability. However, when the model consisted of triangular shapes throughout, the truss was stable.

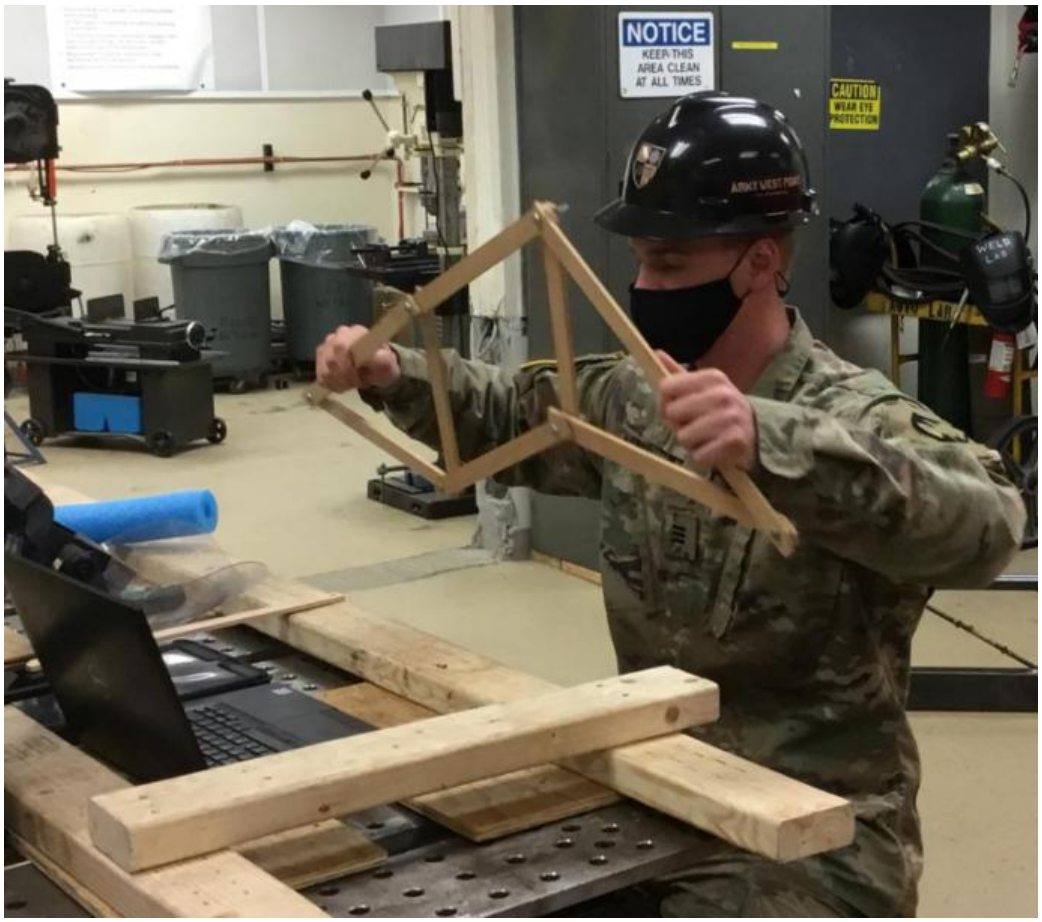

Fig 6. Demonstrating the importance of triangles for a stable truss

Block 4 of the STEM module was devoted towards testing the towers built by each of the four teams and identifying any lessons learned in the success or failure from each test. Each team had a requirement to design and build a 12 ¾ inch tower (minimum height) to hold two bricks for at least five seconds. After the test, each group communicated why their tower was successful, how it could have been better, or what caused it to fail. The winning team was the one with a tower that met the criteria while using the fewest number of K'NEX pieces in construction. As shown in Figure 7, the authors demonstrate an overdesigned tower that held more than two bricks.

Fig 7. Demonstration of the tower testing block

The final block of the module gave the authors an opportunity to assess student learning. The authors made appropriate use of technology by using *Kahoot!,* a low-threat, fun, and engaging way to assess student learning while maintaining enthusiasm. The ten multiple-choice and True/False questions, shown in Table 1, were relevant questions directly tied to the material just presented in the module.

Table 1. Kahoot Questions and answers

Kahoot Question	Answer
What is the name of a structure made of slender members which are joined together at their end points?	Truss
To design trusses, we assume loads are only applied at the joints.	True
A simple truss is in the shape of a _____.	Triangle
When a vehicle drives over a bridge, the bottom chord of the bridge is in compression.	False
When a vehicle drives over the bridge, the top chord of the bridge is in tension.	True
If a load is placed on each of the four columns (same material & area but different heights), which will buckle first?	The column with the longest length
How does a long, slender steel member in compression fail?	It buckles
When bridges are extended over long distances, then _____.	A support is used at one of the joints
A member in tension fails the same way as one in compression.	False
STEM is fun! I will consider pursuing STEM as a potential career field.	True

In addition to the interactive assessment, this block served to provide closeout messages to inspire the students and provide them with an opportunity to ask open-ended questions primarily focused on engineering and college life. Unfortunately, the ethics module preceding the STEM module cut both of the STEM modules short by 15 minutes each. As a result, a complete assessment on student learning using *Kahoot!* did not take place. The complete plan of instruction is provided in Appendix A.

Analysis

The effectiveness of this study was primarily evaluated using surveys. Participating students were provided with a pre-workshop survey to evaluate what they (K-12 students) thought about STEM classes and Art classes. A total of 28 students responded to the survey. The pre-workshop survey included 10 questions on a 5-point Likert scale for how much they agreed with the statements (ranged from strongly disagree to strongly agree). The response from these questions provided insight on the perspectives of the students who were going to take part in the outreach with regards to STEM. The prompts and results of the pre-workshop survey are shown in Table 2 below.

The values in the table below are correlated to the responses for each question. Values were related in this way: Strongly Disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly Agree = 5. For example, the first question's numerical average of 3.54 correlates to an average response between Neutral and Agree in accordance with the question.

Table 2. Pre-Workshop Survey

Survey Prompt	Mean
I enjoy Math and Science classes.	3.54
I enjoy English and reading classes.	3.46
I am interested in Science Technology Engineering and Mathematics (STEM).	2.93
I enjoy Art and other classes that allow me to express creativity.	4.25
I would like a career in STEM.	2.71
I have a family member in a STEM related field or study of work.	2.65
I believe STEM is important.	4.29
I believe STEM is hard.	3.14
I want to go to college.	4.54
I want to study STEM.	2.79

The pre-workshop survey showed that students prefer courses in the Arts that allow them to express their creativity. In addition, 35.7% of those surveyed said that STEM was hard with another 32.1% remaining neutral to that prompt. The misconception that STEM courses do not allow creativity should serve as a challenge to STEM faculty to explicitly identify creative opportunities for students and empower them to consider novel approaches. The misconceptions regarding creativity and that "STEM is hard" likely explains why fewer students in this survey were interested in studying STEM and pursuing it as a career. Combining these feelings with marginal teaching likely led many students to simply settle for mediocrity and a basic understanding when it comes to STEM courses. Recent data supports this suggestion. A Pew Research Center survey shows that 52% of adults believe the main reason young people do not pursue STEM degrees is because they think the subject is too hard [5]. In addition, a test commonly taken by college-bound high school students showed that only 20% of college-bound students are adequately prepared for courses required for a STEM major at the college level [15].

After conducting the engaging, hands-on, and enthusiastic virtual workshops with the students, the students were given a post-workshop survey. A total of 40 students responded to the post-workshop survey. This survey included six questions on a 5-point Likert scale for how much they agreed with the statements (ranged from strongly disagree to strongly agree). The prompts and results of this survey are shown in Table 3.

Table 3. Post-workshop Survey

Survey Prompt	Mean
I enjoyed using the West Point Bridge designer software.	3.55
The K'NEX tower building exercise increased my interest in STEM.	3.18
I am more likely to consider taking STEM classes in the future because of this activity.	2.88
This exercise makes me want to know more about STEM.	3.08
I feel like I could succeed in a STEM class.	3.09
The Kahoot was fun and helpful in making me think about what I learned from the lesson.	3.28

The students were inspired, and their attitudes regarding considering a pursuit in STEM changed because of the STEM module. In fact, there was a 19% increase in the percentage of students

who wanted to know more about STEM as compared to the pre-workshop survey. The survey also pointed out that 33% of the students specifically pointed to the hands-on, engaging, and fun K'NEX tower build was a large reason for this change. Additionally, despite giving five lessons of material in five minutes, the ability to show the material through demonstrations made it easy for the students to understand the material. 72.7 % of the students now felt as though they could succeed in a STEM class (24.2% of the students remained undecided). This optimism regarding personal success in STEM shows how effective an engaging exposure to STEM can be in cultivating excitement and generating curiosity as to future opportunities. It also showed the feasibility to effectively convey STEM in a restricted, COVID-19 environment.

One of the greatest challenges experienced in this study occurred at the individual student level. Each of the high school students that participated in the virtual STEM workshop was in their own personal home environment, which is not ideal. In fact, one student was observed leading their team by designing and building their K'NEX bridge from inside their automobile. A controlled classroom environment would undoubtedly improve the effectiveness and efficiency of the virtual workshop. It was also challenging to gage 100% student engagement when because some students decided to leave their cameras off. In addition, while 20 bags of K'NEX were shipped to Franklin Military Academy, this was not enough for every student to build a tower. The activity was designed for small groups to build each tower in person. The authors did their best to keep everyone engaged by rooting on the identified builder for each team. However, the hands-on activity would undoubtedly increase student engagement and excitement if consolidated in one physical location or if every single student had their own personal bag of K'NEX. Finally, a larger sample size would produce more accurate results on the percentages recorded in this study.

Conclusions and Recommendations

A survey sent to 144 West Point seniors majoring in civil or mechanical engineering in the Fall of 2020 was designed to determine the significant contributors to individuals in their major selection. Of the number of influences provided (upperclassmen, staff & faculty, department recruiting efforts, family and friends, peers and teammates, and department reputation), the greatest influence, by a large margin, was department reputation. Based on that feedback, it should be no surprise that when the same group was asked if they decided on their major before coming to college, 74.7% of the 87 respondents (60.4% response rate) responded yes. The time to inspire students to major in STEM is during their K-12 education. STEM workshops, like this one, can go a long way in inspiring the next generation of STEM majors.

While COVID-19 and subsequent social distancing and virtual environment creates several challenges, engaging, inspiring, and educating students can be done. It requires creativity, structure, enthusiasm, flexibility, physical models, demonstrations, appropriate use of technology, and extra effort, but the payoff of student learning is worth it. One of the biggest lessons the STEM group learned was the value of rehearsals, especially when it involves an unfamiliar technology. Investing the extra time to become proficient in the virtual environment serves a tremendous benefit to the students. A well-rehearsed performance also enhances the odds to keep the attention of the easily-distracted virtual students. In the end, the authors were able to do just that – inspire the next generation of STEM students.

Finally, an outcome that was outside the scope of this paper is the positive impact this experience had on the university students that led the STEM module. Their comments to their faculty advisors can best be summed up with the Latin proverb “Docendo discimus” meaning “by teaching, we learn.” While the fundamentals of trusses were topics they initially learned two years prior and one that was reinforced in subsequent courses throughout their undergraduate studies, it was clear to them that executing and explaining a demonstration is a lot different than observing their instructor doing the same. Participation in the STEM module also provided them the opportunity to develop in a couple of their program’s student outcomes. It allowed them to demonstrate their ability to communicate effectively with a range of audiences. In addition, it provided them with another opportunity to function effectively as a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives. Their ability to meet their objectives, and in fact, surpass all expectations can best be demonstrated through a quote from a retired Brigadier General with close ties to Franklin Military Academy, *“[This was] a great event...probably the most significant Zoom Conference I have attended this year. If the Richmond West Point Society can provide Franklin and other Schools with kits, the ability for 360 Cradle to Careers (C2C) to have greater impact becomes a model that is replicated across the country. Movement is minimized but access and mentoring both for the events and post counsel are possible. West Point Cadets were phenomenal and as an advertisement for what I believe is the Nation's best holistic development university. Again, ... may have created the core of how to advance the concept of C2C in a pandemic and beyond.”*

Appendix A: Plan of Instruction provided to Franklin Military Academy

Since the formation of our nation, civil society and the military have relied on engineers to create and to design. The engineer is charged with envisioning, studying, and creating useful works that serve to sustain and serve humankind and the natural world in which we live. The ability of engineers to deliver useful works is an essential underpinning of modern society. Engineering, especially as it applies to design, is an art informed by experience and science. Mathematics, physics, chemistry, in fact all the practical sciences describe in detail the world as it is. These descriptions, these theories and facts and observations become fundamental tools for the engineer as we work to create a better world.

How do we inspire the next generation of engineers? Studies from the Journal of Science Education and Technology have shown that the best ways to spark curiosity in the STEM field is through hands-on activities. This K-12 STEM breakout session is geared towards generating interest in the field of civil engineering through the design of trusses. This rigid framework of straight, slender members joined at their end points and loaded only at the joints is typically made of steel or wood members that are connected using bolts, rivets, or welds. In this breakout session, students will apply simple math and science to determine how trusses work, calculate the forces (tension and compression) that exist inside the slender members, and understand the advantages of using trusses. Students will work together in teams to design and build a security tower of a specified height that can support troops and equipment. The towers will be tested for strength and stability and bring STEM concepts to life, inspiring students to consider the possibilities of pursuing a STEM field in the future.

Practical Exercise:

Due to a recent hurricane in the Richmond area, one of the security towers at Richmond International Airport was damaged. This tower must be replaced as soon as possible, and the US Army Corps of Engineers is the lead construction agency for the project. They are looking for the lowest cost tower that can support the required guards and surveillance facility off the ground to ensure the local area is secured. Each of the four teams from Franklin Military Academy will have an opportunity to design, build, and test their proposal to the US Army Corps of Engineers. Their proposal is due in 15 minutes. To inspire and provide technical support along the way, each team will have a West Point Civil Engineering student assigned to them during the design and build.

-Organize students into four teams.

-School requirements:

1. Two bricks (or similar)
2. A ruler to measure the towers (preferably one per group)
3. Virtual connections for the four teams

-Provide teams with K'NEX and design requirements:

1. Minimum of 12-3/4" tall tower
2. That can support two bricks for a minimum of five seconds
3. Tower with fewest pieces that meets requirements is the "winner"

At least one day prior to session:
-Provide them with a short video on building trusses with K'NEX (5 min):
https://www.youtube.com/watch?v=asgV1Sy1bjo
-Provide them with the student-made West Point Bridge Designer (WPBD) video
-Invite them to download and explore the WPBD
https://www.cesdb.com/west-point-bridge-designer.html
-Preconception check/survey

Block I – Rapport and Orientation (4 Cadets, 5-10 minutes)
-West Point Cadet introductions
-What is civil engineering? Why is it important? Why did you decide to major in civil engineering? Why are you studying civil engineering at West Point?

Block II – Building the Guard Towers (15 minutes)
-Students teams will design and build a guard tower that meets the design criteria. Cadets will encourage the students on group channels and answer questions while the building proceeds.

Block III -The 5 W's of Trusses in 5 Minutes (5 minutes)
-Orientation.
-Definition: A Truss is a structure that "consists of two-force members only, where the members are organized so that the assemblage as a whole behaves as a single object."
-Demonstrate the two different forces (tension and compression) acting in a truss. Two-force members are structural elements which are subjected to only two forces. The two forces acting on it must have equal magnitude and must be opposite in direction.
*Show tension and compression on the top and bottom of a foam beam.
*Show difference of tension and compression behavior with noodle.
*Show difference in compressive strength (different lengths, materials, sizes).
-Demonstrate and identify the purpose of zero force members (ZFMs) in a truss. ZFMs increase stability and rigidity of the truss and provide support for various loading conditions.
-Demonstrate the use of software to design a truss bridge (WPBD). Video example also provided ahead of time to the school.

Block IV – Testing and Lessons Learned (5-10 minutes)
-Test each tower, one at a time (adequate height, strength, and stability).
-Determine which bridge uses the least number of pieces and meets all of the requirements.
-Key take-away(s).

Block V – Assessment and Closeout (5-10 minutes)
-Game: Kahoot!
-Close-out with closing message to inspire future engineers.

After the session:
-Student survey about effectiveness of outreach.

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