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Virtual Introduction to Engineering Workshop for High School Math Teachers (Work in Progress)

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Introduction

Professional development for K-12 math teachers is a challenging task requiring a careful balance of content and activity to effectively present that content and keep participants engaged. The method of delivery was particularly challenging in 2020 due to the unprecedented COVID-19 pandemic, and many were forced to convert materials from in-person into virtual formats. While there will not likely be anything to replace the benefits of in-person workshops, the on-the-fly conversion to virtual formats has provided some valuable lessons about content delivery for teacher professional development workshops and engineering outreach programs. This paper presents an overview of a virtual introduction to engineering workshop for high school math teachers, along with a concise quantitative analysis of a TESS survey and a qualitative assessment of a focus group conducted at the end of the workshop. The purpose of the study was to simply determine if a virtual workshop could improve teachers' self-efficacy like other in-person workshops have in the past.

Background

The Department of Education's Gaining Early Awareness and Readiness for Undergraduates Programs (GEAR UP) program focuses on improving college readiness among students from low socioeconomic backgrounds [1]. The activities vary considerably across awardees ranging from after school programs for students to professional development programs for teachers and vary in subject matter from writing to math and even general information about post-secondary opportunities and careers. In recent years, STEM programs have landed on the top of many awardees' priority lists. Teacher-focused engineering outreach programs generally consist of professional development opportunities to improve teachers' engineering awareness and ability to teach engineering related content [2, 3]. The ultimate goal is to increase student interest and engineering awareness by integrating content within math and science classes [3-5]. However, most approaches focus more on incorporating engineering principles rather than teaching math and science in the context of engineering [2, 6-9]. Carroll et al. [5] presented their lessons learned from a long-term project focused on afterschool STEM activities in conjunction with a GEAR UP partnership grant. They also noted how those lessons learned influenced their approach for a project with a second grant bringing attention to professional development for math teachers to efficiently bring engineering into the classroom. This second project focused on experiential learning module development coupled with professional development opportunities for math teachers. The initial success of the second project also sparked a second partnership with a different GEAR UP grant, resulting in a three-day on-site professional development workshop in the summer of 2019 at Oregon State University for 22 middle and high school math teachers [10]. A similar project funded through Boeing was completed in the spring of 2020 in St. Louis just prior to the COVID-19 shutdowns with 20 additional math teachers. The second Lafayette Parish GEAR UP grant was in year six of seven at the time of the shutdowns and the only option for continuing professional development opportunities for teachers was to use a virtual format.

Workshop Format

The virtual workshop took place from June 30, 2020 through July 2, 2020 consisting of both synchronous and asynchronous content. The synchronous portion of the workshop ran from 11:00 am to 1:00 pm each of the three days via Zoom and the asynchronous tasks primarily took place during the evening of Day 1 and Day 2. All electronic materials were made available through Thinkific.com and each participant received all of the necessary physical materials prior to the workshop. Table 1 shows a detailed schedule for the virtual workshop.

Table 1—Workshop Schedule

Time	6/30 Tuesday	7/1 Wednesday	7/2 Thursday
Synchronous Sessions			
11:00 am	Introductions	Gravitational Acceleration Module	Participant Presentations
	Introduction to Engineering		
11:30 am			
		Cubic Functions and Volumes Module	
12:00 pm	K’Nex Tower Module		TESS Post-survey
			Focused Discussion
12:30 pm		Create your own module	
Asynchronous Tasks			
Evening	Record your own tennis ball drop video	Create your own module	

The virtual workshop began with an *Introduction to Engineering* presentation following brief self-introductions by all the participants. The presentation included three primary parts. The first part of the presentation focused on “understanding your students” including a discussion of how students learn and the typical learning styles preferences of engineering students. The second part defined “engineering” and “technology,” discussed the differences between the two, and provided brief overviews of aerospace, biomedical, chemical, civil, electrical, mechanical, nuclear, and petroleum engineering. The third part focused on the importance of math in engineering by presenting a typical biomedical engineering curriculum and illustrating the importance of completing Calculus I during the first semester of college and how being prepared to do so traces back to students’ middle and high school preparation.

The first synchronous activity was the *K’Nex Tower Module* [10], which requires students to physically construct an observation tower with a minimum height of 18 in. with only four contact points using a predetermined amount of K’Nex. The objective was to minimize the perimeter of the base to reduce the environmental impact on the surrounding area, while also maximizing the perimeter of the viewing platform to increase the space for tourists to view the surrounding area. Each of the participants was given 30 minutes to build their towers and were encouraged to complete the module as if they were a student. Prior to load testing the towers, students would be asked to calculate the perimeter of the base and viewing platform along with the surface area of the sides. Those calculations were not completed by the participants due to time constraints, but each tower was load tested using various materials available to the participants.

The second synchronous activity was the *Gravitational Acceleration Module* [10], which requires students to experimentally and approximately determine the gravitational acceleration constant. Prior to the start of Day 2, participants were asked to create a slow-motion video with their smart phones of a tennis ball falling from a height of 8 ft with 1 ft increments on the wall. Each participant was provided with a tripod, remote trigger, tennis ball, and masking tape to create the video. During the workshop participants worked in two groups of three via breakout rooms to plot the position versus time of each group member in a premade Google sheet.

The third synchronous activity was the *Cubic Functions and Volumes Module* [10], which requires students to physically create a series of five-sided boxes by cutting out four squares (x by x) from the corners of eight pieces of 8 by 10 card stock using values of x = 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0, and then folding the sides up to make boxes. Participants constructed all of the boxes, calculated the volumes of each box, and then plotted the volume of each box with respect to the x-value used to cut out the corners. The objective is to experimentally determine the x-value that would maximize the volume of the box.

Lastly, participants were given 30 minutes at the end of Day 2 to start on their *Create Your Own Module* activity. Participants received a template and instructions to 1) connect to an existing standard used in the course of their choice, 2) highlight a STEM career and include an introduction to that career, 3) highlight the completion of a degree (e.g. associates, bachelors, masters, etc.), 4) be reasonable for one class period, and 5) include related photos, figures, tables, etc. Participants completed a working draft of their module asynchronously during the evening of Day 2 and then presented their modules at the beginning of Day 3 for feedback from their peers.

Methodology

A total of six teachers participated in the virtual workshop. Each participant was asked to complete the Teaching Engineering Self-Efficacy Scale (TESS) survey [3] before the workshop began and after the participant presentations on Day 3. The TESS survey is a tool that was developed to measure teacher preparedness in regard to engineering related content, with a total of 23 questions divided into five categories (Engineering Content Knowledge, Instruction, Engagement, Discipline, and Outcome), where responses were on a 6-point Likert-type scale, ranging from Strongly Disagree to Strongly Agree. Participant scores were given a quantitative value from 1-6 based on their respective answers, and descriptive statistics were calculated for each of the categories. The six participants were also asked to participate in a focused discussion to conclude the workshop. All six participants completed the pre- and post-workshop TESS surveys, and five of the six participants were included in the focused discussion. The sixth participant was unable to attend Day 3 but did answer the questions used for the focused discussion electronically. The focused discussion included eight questions as listed below:

1. Can you tell me about the Professional Development climate within your school system for math teachers?
2. What motivated you to participate in this Professional Development program?
3. What challenges do you anticipate by incorporating these activities in your classroom?
4. What benefits do you anticipate by incorporating these activities in your classroom?

5. How did your comfort level with engineering change as a result of participating in the program?
6. Would you be interested in participating in continued virtual professional development throughout the academic year? (Yes or No)
    a. What particular areas, topics, and/or teaching methods would you be interested in learning more about?
7. Would you recommend this GEAR UP Professional Development program to other educators? Why or why not?
8. Is there anything else that we didn't discuss that you'd like to share?

Results

TESS Survey

The data from the pre- and post- TESS surveys were coded, and each response was given a quantitative value, which was used for data analysis. Table 2 provides a summary of the data broken down by factor. *Engineering content knowledge* refers to the teachers' personal beliefs on their own knowledge of engineering and their ability to incorporate that knowledge within their teaching curricula and includes eight questions. *Instruction* refers to the instructors' personal belief in their ability to teach engineering in order to facilitate learning and includes one question. *Engagement* refers to the teachers' belief in their ability to engage their students while teaching engineering and includes 4 questions. *Disciplinary* refers to the instructors' personal belief in their confidence to handle student behaviors during engineering activities and includes five questions. *Outcome expectancy* is teachers' personal beliefs that their ability to teach engineering is impacting the learning outcome of their students and includes five questions [3]. The raw data showed substantial ranges between minimum and maximum scores for the pre- and post-surveys, which resulted in large standard deviations for each factor. While each factor shows an increased average score between pre- and post-surveys, the small sample size coupled with the large standard deviations resulted in no statistically significant differences between means of the pre- and post-surveys for any factor based on a paired t-test.

Table 2 – Descriptive Statistics of TESS Pre & Post Surveys

Factor (max score)	Pre-survey (n = 6)		Post-survey (n = 6)		p-value
	Mean	St. Dev.	Mean	St. Dev.	
Engineering Content Knowledge (48)	25.83	8.13	33.47	7.45	0.11
Instructional (6)	3.65	1.66	5.05	1.28	0.41
Engagement (24)	16.70	6.18	20.70	5.25	0.80
Disciplinary (30)	22.35	7.88	24.65	6.98	0.75
Outcome Expectancy (30)	21.15	6.69	24.60	6.12	0.57

Focus Group

Teachers indicated that during typical professional development opportunities the facilitator "*throw[s] a lot of stuff at you and hope that you understand what's happening.*" This can be overwhelming and may result in teachers choosing only one aspect to implement or a small tweak to their lesson plan. Overall, the teachers indicated only 25-50% of their past professional development experience has been incorporated into their lessons.

This lack of implementation was attributed to time. Before using a new lesson in the classroom, teachers work through the assignment themselves to identify "*where the potential sticking points"* are and then revise the lesson accordingly. In addition to the time required to prepare a new lesson, curriculum pacing was cited as the main constraint. K-12 teachers do not have the flexibility and autonomy over their courses that educators in higher education have. The teachers shared frustration over trying to balance activities to help students better understand course content with being accountable to administrators if they fall behind mandated pacing.

Despite the limitations in implementation, the teachers still found the professional development program worthwhile. They reported increased comfort with engineering concepts as portrayed in the following participant quote:

"I think it's not as intimidating as I might've thought before. What we don't know, I think intimidates us, and we research and we study more. Helps us to be more at ease with. So, I really enjoyed it."

In addition to their own increased understanding, the teachers anticipate a similar impact on their students once they implement the activities in their own classes. Not only are the activities viewed as more motivating for students, but also provide relevance of the content to daily life. As one teacher stated:

"And I always tell my students, 'Math is everywhere. It's being used.' Because, they're always telling me, 'When am I going to use this?' And maybe it'll give them an opportunity to actually see how the math can be used and have confidence that they know how to do the math because they do. They do know how to do the math, they just don't think they know how."

Lessons Learned and Future Work

The COVID-19 pandemic created many challenges for the educational system, one of which included the inability to meet in person. Although proven to be more effective, in-person training and learning sessions were not an option, thus the need to improvise and create online workshops became necessary. The virtual Introduction to Engineering Workshop was able to highlight many important positives and negatives about engineering outreach programs. Teacher self-efficacy appeared to improve over a short program and teacher responses to the focus group echoed many concerns and frustrations heard many times over. The workshop fulfilled a short-term need in an extraordinary time, and while the workshop showed promise for improving teachers' engineering self-efficacy, such formats will likely never take the place of in-person workshops. There is simply no substitute for in-person interactions and the energy associated with cooperative learning environments. However, there may be benefits to mixed approaches or asynchronous formats that utilize the technologies so many learned to use during the past year. First, the virtual format could be used for follow-up meetings and short refresher sessions to efficiently help teachers problem shoot issues that arose during implementation. Second, asynchronous formats similar to those used in this workshop could also provide opportunities for teachers unable to attend formal professional development opportunities to progress at their own pace based on their needs. The authors plan to incorporate virtual aspects in future workshops and will continue to study the effect of such offerings on teachers' engineering self-efficacy.

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References

1. *Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP) Purpose*. 2015 January 2, 2017]; Available from: https://www2.ed.gov/programs/gearup/index.html.

2. Brophy, S., et al., *Advancing Engineering Edcuation in P-12 Classrooms.* Journal of Engineering Education, 2008. **97**(3): p. 369-387.

3. Yoon Yoon, S., M.G. Evans, and J. Strobel, *Validation of the Teaching Engineering Self-Efficacy Scale for K-12 Teachers: A Structural Equation Modeling Approach.* Journal of Engineering Education, 2014. **103**(3): p. 463-485.

4. deGrazia, J.L., et al., *A K-12/University Partnership: Creating Tomorrow's Engineers.* Journal of Engineering Education, 2001. **90**(4): p. 557-563.

5. Carroll, J.C., et al. *Lessons Learned in K-12 Engineering Outreach and Their Impact on Program Planning*. in *2017 ASEE Annual Conference and Exposition*. 2017. Columbus, OH: American Society for Engineering Education.

6. Douglas, J., E. Iverson, and C. Kalyandurg, *Engineering in the K-12 Classroom: An Analysis of Current Practices and Guidelines for the Future*. 2004, American Society for Engineering Education: Washington, DC.

7. Bogue, B., et al., *Outcomes-Based Assessment Driven Outreach Program Effectiveness.* Leadership and Management in Engineering, 2013. **13**(1): p. 27-34.

8. Sanoff, A.P., *Building Tomorrow's Workforce*, in *ASEE Prism Online*. 2001.

9. Rockland, R., et al., *Advanacing the "E" in K-12 STEM Education.* The Journal of Technology Studies, 2010. **36**(1): p. 53-64.

10. Syed, S.M., et al., *Professional Development for K-12 Math Teachers and Its Immediate Effect on Engineering Self-Efficacy*, in *2020 ASEE Virtual Conference*. 2020, Ameriican Society for Engineering Education.