INSPIRING TRANSPORTATION CAREERS WITH K-12 CURRICULUM ACTIVITES

FINAL PROJECT REPORT

by

Olivia Willis and Michelle Akin
Washington State University

Sponsorship
PacTrans

for
Pacific Northwest Transportation Consortium (PacTrans)
USDOT University Transportation Center for Federal Region 10
University of Washington
More Hall 112, Box 352700
Seattle, WA 98195-2700

In cooperation with US Department of Transportation- Office of the Assistant Secretary for Research and Technology (OST-R)

Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the U.S. Department of Transportation's University Transportation Centers Program, in the interest of information exchange. The Pacific Northwest Transportation Consortium, the U.S. Government and matching sponsor assume no liability for the contents or use thereof.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
	01701487	

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code
Inspiring Transportation Careers with K-12 Curriculum Activities	**5. Report Date** December 2019 **6. Performing Organization Code**
7. Author(s) Olivia Willis and Michelle Akin ORCID# 0000-0001-6349-8481	**8. Performing Organization Report No.** 2018-S-WSU-2
9. Performing Organization Name and Address PacTrans Pacific Northwest Transportation Consortium University Transportation Center for Region 10 University of Washington More Hall 112 Seattle, WA 98195-2700	**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** 69A3551747110
12. Sponsoring Organization Name and Address United States of America Department of Transportation Research and Innovative Technology Administration	**13. Type of Report and Period Covered** Final Report, August 2018 – December 2019 **14. Sponsoring Agency Code**

15. Supplementary Notes

Report uploaded at www.pacTrans.org

16. Abstract

Shortages in the transportation industry have resulted in an increasing need to be able to attract new employees. Two methods of outreach that have been successful at increasing awareness and interest in transportation careers in local youth have been working directly with students and training the teachers. This project worked directly with students by conducting outreach events that involved either hosting a table at a large science event where students would stop for short periods of time to complete the activities or working with a group of students for a designated block of time for consecutive days. Hands-on activities such as toothpick and gumdrop bridges, clothespin cars, and wind-up cars were explored, as well as demonstrations involving gears, a gyroscope, or a pull-back rubber band car. The activities available at each event were chosen on the basis of the duration of time researchers would have with each student and the number of students expected to be present. Engaging the age range of K-12 proved difficult with a single activity, as younger students took more interest in activities with continuous guidance from the researchers, whereas older students were more invested if they were able to complete the activity with minimal, or no, guidance. Both preferred hands-on activities over demonstrations. A drawback to the outreach events was that few middle or high school aged students were present. In future research, one might consider exploring the influence of self-efficacy on students' performance, how gender relates to self-efficacy and learning, and outreach events aimed at teachers rather than students.

17. Key Words	18. Distribution Statement
K-1 Outreach, Transportation Outreach, STEM Outreach	No restrictions.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified.	Unclassified.		NA

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorize**

Table of Contents

List of Tables

List of Figures

Acknowledgments

The authors would like to thank Dr. Xianming Shi for his guidance in the conceptualization and conclusion of this project and in the creation of this report. They also would like to thank Imry Gaber and Nicole Kim for their assistance in running outreach events.

Executive Summary

As the transportation industry faces shortages in its workforce, it is becoming increasingly important to be able to attract new employees. This project aimed to increase awareness and interest in transportation careers in local youth through outreach events. Previous literature has suggested that two different methods of outreach have proved successful for this exposure: working directly with students and training teachers. This project worked directly with students by conducting outreach events that involved either hosting a table at a large science event where students would stop for various periods of time to complete activities or working with a group of students for a designated amount of time (typically longer than that at the tabling events) for consecutive days. Hands-on activities such as toothpick and gumdrop bridges, clothespin cars, and wind-up cars were explored, as well as demonstrations involving gears, a gyroscope, or a pull-back rubber band car. The activities that were available at each event were chosen on the basis of the duration of the time researchers would have with each student and the number of students expected to be present. Elementary and middle school students both responded better to hands-on activities than to demonstrations, as they were more engaged with and focused on the activity at hand. Younger students took more interest in activities with continuous guidance from the researchers, whereas older students were more invested if they were able to complete the activity with minimal, or no, guidance. Older students also liked to be given an incentive, such as an activity with a competition aspect. A drawback of the outreach events was that few middle or high school students were present. In future research, one might consider exploring the influence of self-efficacy on students' performance, how gender affects the before-and-after scores on a learning check of the STEM outreach content, and how holding outreach events aimed at teachers rather than students might influence the results.

Chapter 1: Introduction

As the world becomes faster paced and more technology-driven, it is becoming increasingly important for children to gain a better understanding of science from a young age (Tillinghast and Mansouri, 2016; Kesidou and Koppal, 2004; Curtis, 2017). This is especially relevant in the transportation industry. As the industry faces workforce shortages, the need to foster an understanding of transportation in young children to encourage them to join the industry has become critical. Most textbooks do not sufficiently teach science, technology, engineering and math (STEM) information or grow students' passion for STEM (Kesidou and Koppal, 2004).

Outreach events may be a good way to provide this early exposure. By participating in outreach events, students are able to see that a career as a scientist is attainable, interesting, and not as out of reach as they may feel before the event (Muller et al., 2013). Researchers are attempting to tackle this issue in two ways. The first involves outreach events with direct exposure of engineering material to elementary, middle, and high school students. The other involves more extensive training for teachers so they can more effectively emphasize the significance of math and science in the classroom. Both approaches focus on hands-on learning. With the vast array of different outreach possibilities, this project sought to design hands-on outreach events that focused on multimodal transportation, would motivate local children to become further interested in STEM and consider a career in engineering, and would allow the researchers to determine the most effective method of outreach to accomplish their goal.

Chapter 2: Literature Review

Many studies have reached the conclusion that students learn best via active learning (Thomas, 2012; Ward, et al., 2015; Worcester et al., 2013; Zhou, et al., 2017). Students tend to lose interest and do not engage themselves in passive learning (Zhou et al., 2017). Examples of passive learning include presentations, demonstrations, and lectures. These methods can be turned into active learning by interacting with students more by asking questions or encouraging them to take part in the demonstration. Hands-on and game-like activities have been shown to be successful at both engaging students and teaching them (Liao, et al., 2010). Liao's study incorporated an interactive, web-based traffic control simulation game at a high school summer camp (2010). The students reported feeling excitement about the game and more awareness of traffic engineering issues (Liao et al., 2010). A project called Adventure Engineering utilized adventure scenarios in which students had to learn specific mathematical or scientific skills to navigate their way through the adventure (Mooney and Laubach, 2002). Mooney and Laubach's research showed that not only did the students learn the material better than the control groups in a normal classroom setting, but they also had significantly more interest in learning via this method (2002).

Showing students examples of individuals who work in various STEM careers or college students studying science has been found to help students picture themselves in a STEM profession (Levine, et al., 2015). Students who have family members in a STEM career are more likely to pursue a career in a STEM field (Zhou et al., 2017). This may be because the students have the opportunity to see that a scientist has the appearance of a typical person and doesn't always fit the stereotypical appearance of a man with white hair in a lab coat. Moskal et al. studied a program that incorporated graduate students working with students (2007). As a result, the students had graduate students and faculty to look up to as scientists who were real and differed from the stereotypical appearance (Moskal et al., 2007). When students are exposed to a variety of different scientists, they may feel that a career in STEM is within reach, allowing them to picture themselves in the role as they see similarities between themselves and real scientists.

Outreach events targeting teachers rather than students have also provdn to be effective (Moskal et al., 2017; Sewry, et al., 2014). The Colorado School of Mines notably held outreach events that focused on improving teachers' knowledge of the subject(s) that they taught so that they not only could relay better information to the students but could also be more prepared to create hands-on activities and real-world examples that would help kids learn more effectively and efficiently (Moskal et al., 2007). This had a great impact on not only the students but also the faculty and graduate students, as explained by Moskal (2007). Moskal's study reported that this project greatly increased students' understanding of math and science and their interest in learning because of the teachers' new abilities to make the activities more hands-on and provide real-world examples of the content (2007). Teachers who attend workshops can increase their knowledge of their teaching subject and improve their confidence while finding ways to teach more practical and interesting lessons in which students are more engaged (Sewry et al., 2014).

Chapter 3: Methodology

Outreach events were conducted either by hosting a table at a large science event where kids could walk around and stop at tables for various amounts of time to complete different activities or by working with a large group of kids for a two-hour block at a day camp. The hands-on and interactive activities that were conducted at the table events included toothpick and gumdrop bridges, clothespin cars, and wind-up cars. For the toothpick and gumdrop bridges, children were given a diagram of different bridge designs and a surplus of toothpicks and gumdrops (figure 3.1). The children could then either follow a design on a provided diagram (figure 3.2) or create a design of their own to build a bridge. The bridge's strength was then tested by placing rolls of pennies on the center of the bridge while each end was sitting on a stack of books. They created clothespin cars by putting a gumdrop on either side of two toothpicks and placing the toothpicks inside the clothespin at the spring and taped into the clamp part. They created wind-up cars by pulling a rubber band through a foam cup, through lids (paper plates were used in this program) on either end of the cup, and then attaching a stick to one end of the rubber band with the help of a bead and a paperclip to the other end of the rubber band (figure 3.3).

Figure 3-1: Hands-on bridge building

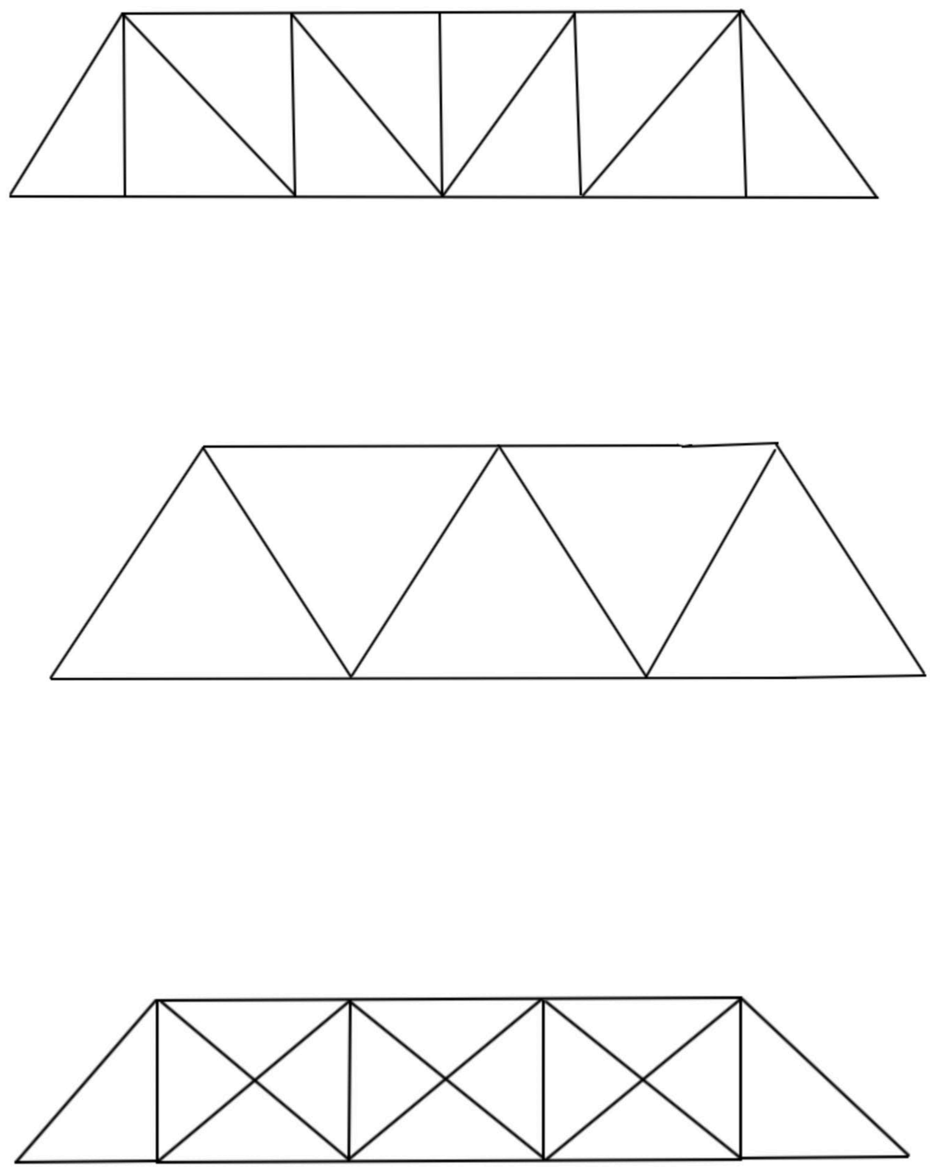

Figure 3-2: Bridge design handouts

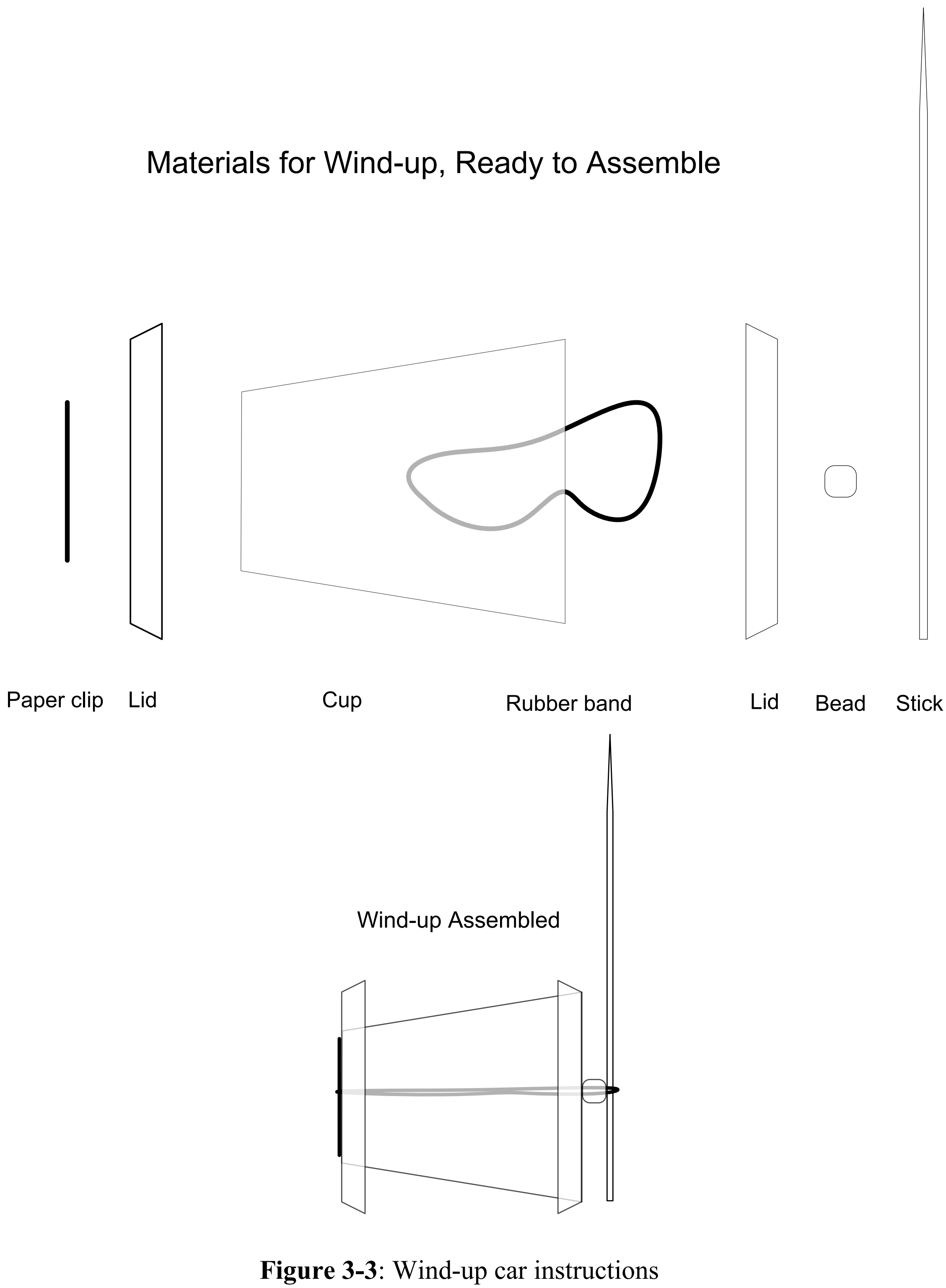

Figure 3-3: Wind-up car instructions

Demonstrations were also conducted at some of the events, including a gears demonstration, a pull-back rubber band car (figure 3.4), and a gyroscope. The gears demonstration consisted of 3D printed gears of different sizes that the kids could twist and see which fit together best. The kids were instructed to count the rotations of the different gears to see how gear size influenced the necessary number of rotations. The gyroscope was used to demonstrate gravity and pique kids' interest in general, as well as to draw them to the table. The pull-back rubber band car consisted of a large hollow tube with wheels made of CDs and a rubber band twisted around a bar connecting the back wheels of the car and attached to another bar in the center of the car. When the rod attached to the back wheels was twisted, it created tension in the rubber band and caused the back wheels to spin. This was used to show potential energy and how friction causes a car to slow down at different rates on different surfaces.

Figure 3-4: Pull-back rubber band car demonstration

The types of activities available at each outreach event were determined by the duration of time researchers would be able to spend with each student and the number of students expected to be present. At events where the researchers would sit at a table while students stopped at each table for short periods of time, quick demonstrations were often paired with more time-intensive hands-on activities such as gumdrop-toothpick bridge building or wind-up cars. This provided an engaging learning opportunity both for kids who stopped at the table for less than a minute and those who stayed at the table for 20 minutes. At events where the researchers would be working with students for extended periods of time, such as the two-hour blocks, activities were chosen that could be explained in detail and that would allow kids to be creative, such as the gumdrop-toothpick bridge building. This activity was well-suited for two-day consecutive outreach events with the same students because the first day focused on building a bridge and the second focused on testing the strength of the bridge. This was done by placing rolls of pennies on the center of the bridge until a toothpick snapped.

Both qualitative and quantitative data were collected at the outreach events. Quantitative data included attendance counts. The number of kids who stopped at the researchers' table at the tabling events was totaled at each event. Qualitative data included how invested the kids seemed in the activities, whether they moved on to another table before completing the activity, and whether they were focused on the demonstrations. These data were analyzed as a whole to determine which activities seemed to be the most effective at engaging the students. Table 3.1 summarizes the outreach events attendance and activities.

Table 3.1: Outreach events attendance and activities

Location of Event	Type of Event	Attendance	Ages Targeted	Activities
Franklin Elementary School STEAM Night	Tabling event	40*	Elementary	Wind-Up cars
Garfield-Palouse Family STEAM Night	Tabling event	80*	Elementary and few middle	Physics gyroscope, pull-back rubber band car, gears demonstration
Saint John STEAM Night	Tabling event	200*	Elementary	Wind-up car, gears demo, alternative fuels display, balloon car
Franklin Elementary Science Fair	Tabling event	80	Elementary	Gumdrop-toothpick bridges, win-up cars, gumdrop cars
9th Annual Nez Perce Tribe STEM Fair	Tabling event	240*	Middle School	Wind-up cars, alternate fuels display, balloon cars, steam powered boat
Kids Science and Engineering Day	Tabling Event	230*	Elementary and some middle	Gumdrop-toothpick bridges, wind-up cars
Moscow Adventure Club, McDonald Elementary	2-hour blocks with kids for 2 consecutive days	47 on day 1 59 on day 2	Elementary	Gumdrop-toothpick bridges, clothespin-gumdrop cars
YMCA of the Palouse, Sunnyside Elementary	2-hour blocks with kids for 2 consecutive days	28	Elementary	Gumdrop-toothpick bridges, clothespin-gumdrop cars

*estimated value

Chapter 4: Results and Discussion

Overall, the elementary students actively participated in the hands-on activities but lost interest in the demonstrations at tabling events. The younger kids thrived with the assistance and constant guidance of the researchers. When bridges were made, for example, the younger kids found more success and seemed to enjoy the activity more if a researcher walked them through the process of building the bridge step by step and gave them a bridge design to follow (figure 3.2). When presented with demonstrations such as the gyroscope or gears, elementary-level students watched and asked questions at first but then quickly stopped watching or moved onto another table. This supports the findings of Thomas (2012), Ward et al. (2015), Worcester et al. (2013), and Zhou et al. (2017), who all noted that active learning was the most engaging and interesting for students.

During the outreach events, only a small number of middle and high school students were present. Not many attended the STEM events, as the events were mainly aimed at elementary students. The middle school students did not respond well to demonstrations. When observing demonstrations, they were easily distracted and not engaged. They would often quickly move on to the next table if only a demonstration was occurring. This observation supports the research conducted by Reisslein et al. (2013). Reisslein found that elementary students were more engaged in an activity that they provided to both elementary and high school students (2013). Our observations suggest that this finding is true for elementary and middle school aged students as well. The events in both our study and Reisslein et al.'s were tailored to be understandable by elementary students, so the level of complexity of the demonstrations may have been part of what caused older students to be less engaged. The bridge-building activity proved to be engaging for middle school students. This activity encouraged students to stay at the researchers' table much longer, which allowed the researchers to explain more of the science behind bridge building to the kids. The older students seemed to enjoy the activity as long as they had the freedom to be creative with the bridge design. If older students were asked to follow a specific bridge design, they either built it very quickly and showed a lack of interest or built something that was either a completely different design or not a bridge (such as a building).

We noticed that the older students were significantly more interested in completing the activity if an incentive was added, such as testing the amount of weight the bridge could hold. A scoreboard was created that ranked the strongest bridges, and this encouraged kids to put more effort into their design; some even made a second bridge after learning the weaknesses in the design of their first bridge. Zhou et al. (2017) found a similar pattern, as they reported that high school students were the most committed to an activity when a competition aspect was involved. The mind sets of the kids were also noted, as a bad attitude seemed to pair with a poorly built bridge. When kids asked a plethora of questions and was engaged in the activity, their bridge turned out to be far superior.

The block sessions that consisted of working with the same, or nearly same, group of kids for two hours on two consecutive days seemed to foster an environment in which the students felt more comfortable asking questions. This could have been due to the students seeing the researchers as normal people through increased interaction with them, rather than as intimidating scientists. Being able to relate to the researchers may have helped the kids picture themselves as scientists, as studies suggested, but data were not collected on this question in this outreach project (Levine et al., 2015). We interacted with fewer kids during the block sessions than at the tabling events, but the quality of the interactions improved, as the researchers were able to walk the kids through the procedures and explain the science behind the topics, such as the gumdrop-toothpick bridges, more thoroughly.

The results suggest that the most effective method of outreach of at tabling events is hands-on. This approach proved to be more engaging than demonstrations for both elementary and middle school students.

Chapter 5: Conclusion and Recommendation

One drawback of this project was that not many middle and high school students attended the STEM events where outreach efforts were conducted, so that most of the researchers' observations were focused on younger kids. This may be because at a certain age, parents stop pushing STEM on kids and taking them to exposure events. This raises the question of whether events that occur outside of normal school hours are realistic for reaching older students. As Mooney and Laubach (2002) discussed, any sort of extracurricular activity will only reach students who are already interested in engineering or STEM enough to attend the event, while leaving behind students at whom the event is truly aimed .

A contest format with a prize, introduced into the mandatory classroom setting, may increase kids' interest as an award for doing well may incentivize them to be innovative and creative, potentially increasing self-efficacy and students' performance. Self-efficacy could be analyzed by giving a before-and-after survey to determine how the contest influenced the students' engagement or success. It would be interesting to see how much time a child who did not believe s/he could successfully win the contest contributed to the project in comparison to someone who strongly believed that s/he could succeed. It is possible that kids' self-efficacy scores might improve from the pre-test to post-test because of an increase in their confidence in their skills during the outreach event (Demetry et al., 2009; Fraze, et al., 2011).

Gender could also be analyzed, as significantly more men currently work in the STEM fields than women; Miyake et al. (2010) proposed that this is due to the identity threat women feel when surrounded by men in STEM classes and environments. Research has found that outreach events are more often the first exposure that girls and those of minority groups have to STEM than for boys and those of the ethnic majority (Ivey, et al., 2012). Because boys are more confident in their STEM skills, they may be expected to have higher self-efficacy scores before an outreach event than girls (Reuben et al., 2014). Depending on how well girls perform, the self-efficacy scores of both the boys and girls might change drastically after an outreach event, as the boys' self-efficacy scores could change in an inverse relationship to those of the girls if they began to feel inferior to the girls. The self-efficacy and gender relationship could even extend past elementary, middle, and high school years into the undergraduate college setting as they search for careers, showing that this is a topic that needs to be analyzed and addressed (Gnilka and Novakovik, 2017). By gaining a better understanding of self-efficacy and its relationship to gender, outreach events could become tailored to foster a growth mind set in both genders, as well as teaching kids about engineering and increasing interest in STEM.

All of the events that were conducted by the researchers were directed toward students. An outreach event could be held in which teachers were the ones being trained, but this would require a long-term commitment to check in on the classroom over time, rather than just the one-hour blocks that the researchers utilized. The self-efficacy and confidence of students' abilities within the targeted teachers' classrooms could also be analyzed, as that could potentially influence how well they were able to administer the material and how they interacted with the students.

Overall, the students responded best to incentives and having the option to be creative in their learning while also knowing that support was available if they wanted it. Learning from their mistakes proved to be more effective than being guided by an instructor. The next step will be to find the best way to incentivize the students while creating a space where they feel safe to learn.

References

Curtis, K. (2017). Science after school: way cool! A course-based approach to teaching scienceoutreach. Advances in Physiology Education, 41(1), 10–15. https://doi.org/10.1152/advan.00107.2016

Demetry, C., Hubelbank, J., Blaisdell, S. L., Sontgerath, S., Nicholson, M. E., Rosenthal, L., & Quinn, P. (2009). Supporting young women to enter engineering: Long-term effects of a middle school engineering outreach program for girls. *Journal of Women and Minorities in Science and Engineering*, *15*(2).

Fantastic Elastic. (n.d.). Retrieved December 19, 2019, from http://www.citytechnology.org/energy-system/fantastic-elastic-.

Fraze, L. B., Wingenbach, G., Rutherford, T., & Wolfskill, L. A. (2011). Effects of a Recruitment Workshop on Selected Urban High School Students' Self-Efficacy and Attitudes toward Agriculture as a Subject, College Major, and Career. *Journal of Agricultural Education*, *52*(4), 123-135.

Gnilka, P. B., and Novakovic, A. (2017). Gender differences in STEM students' perfectionism, career search self-efficacy, and perception of career barriers. *Journal of Counseling & Development*, *95*(1), 56-66.

Ivey, S. S., Golias, M. M., Palazolo, P., Edwards, S., & Thomas, P. (2012). Attracting Students to Transportation Engineering: Gender Differences and Implications of Student Perceptions of Transportation Engineering Careers. *Transportation Research Record*, *2320*(1), 90-96.

Kesidou, S., and Koppal, M. (2004). Supporting Goals-Based Learning with STEMOutreach. Journal of STEM Education: Innovations and Research, 5(3-4), 5–12. Retrieved from http://search.proquest.com/docview/1720060271/

Levine, M., Serio, N., Radaram, B., Chaudhuri, S., and Talbert, W. (2015). Addressing the STEM gender gap by designing and implementing an educational outreach chemistry camp for middle school girls. *Journal of Chemical Education*, *92*(10), 1639-1644.

Liao, C. F., Glick, D. B., Haag, S., and Baas, G. (2010). Development and deployment of traffic control game: Integration with traffic engineering curriculum for teaching high school students. *Transportation Research Record*, *2199*(1), 28-36.

Miyake, A., Kost-Smith, L. E., Finkelstein, N. D., Pollock, S. J., Cohen, G. L., and Ito, T. A. (2010). Reducing the gender achievement gap in college science: a classroom study of values affirmation. Science (New York, N.Y.), 330(6008), 1234–1237. https://doi.org/10.1126/science.1195996

Mooney, M. A., and Laubach, T. A. (2002). Adventure Engineering: A Design Centered, Inquiry Based Approach to Middle Grade Science and Mathematics Education. Journal of Engineering Education,91(3), 309-318. doi:10.1002/j.2168-9830.2002.tb00708.x

Moskal, B. M., Skokan, C., Kosbar, L., Dean, A., Westland, C., Barker, H., . . . Tafoya, J (2007). K-12 Outreach: Identifying the Broader Impacts of Four Outreach Projects. Journal of Engineering Education, 96(3), 173-189. doi:10.1002/j.2168-9830.2007.tb00928.x

Muller, C. L., Roberts, S., Wilson, R. C., Remedios, J. J., Illingworth, S., Graves, R., ... and Desai, A. (2013). The Blue Marble: a model for primary school STEM outreach. *Physics Education*, *48*(2), 176.

Reisslein, J., Ozogul, G., Johnson, A. M., Bishop, K. L., Harvey, J., and Reisslein, M. (2012). Circuits kit K–12 outreach: Impact of circuit element representation and student gender. *IEEE Transactions on Education*, *56*(3), 316-321.

Reuben, Ernesto, Sapienza, Paola, and Zingales, Luigi. (2014). How stereotypes impair women's careers in science.(ECONOMIC SCIENCES)(Report)(Author abstract). Proceedings of the National Academy of Sciences of the United States, 111(12), 4403–4408. https://doi.org/10.1073/pnas.1314788111

Sewry, J. D., Glover, S. R., Harrison, T. G., Shallcross, D. E., and Ngcoza, K. M. (2014). Offering community engagement activities to increase chemistry knowledge and confidence for teachers and students. *Journal of Chemical Education*, *91*(10), 1611-1617.

Thomas, C. L. (2012). Assessing high school student learning on science outreach lab activities. *Journal of Chemical Education*, *89*(10), 1259-1263.

Tillinghast, R., and Mansouri, M. (2016). Influencing factors in identifying the optimal age forconducting STEM outreach. In 2016 IEEE Integrated STEM Education Conference (ISEC) (pp. 128–131). IEEE. https://doi.org/10.1109/ISECon.2016.7457517

Ward, L., Lyden, S., Fitzallen, N., and León de la Barra, B. (2015). Using engineering activities to engage middle school students in physics and biology. *Australasian Journal of Engineering Education*, *20*(2), 145-156.

Worcester, A. C., Hickox, V. M., Klimaszewski, J. G., Wilches-Bernal, F., Chow, J. H., and Chen, C. F. (2013). The sky's the limit!: Designing wind farms: A hands-on STEM activity for high school students. *IEEE Power and Energy Magazine*, *11*(1), 18-29.

Zhou, B., Anderson, C., Wang, F., and Li, L. (2017). Perceptions and Preferences of High School Students in STEM: A Case Study in Connecticut and Mississippi. *Journal of Systemics, Cybernetics and Informatics*, *15*(5), 23-26.