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Outreach Program for Middle and High School Students to Promote Transportation Engineering*

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Introducing children to transportation engineering through outreach is essential to meeting the future need for transportation engineers. An online activity was designed in Qualtrics, consisting of survey questions, a pre-activity test pertaining to transportation engineering, links to educational videos, a transportation game, a post-activity test to gauge learning, and a short essay. Participants were recruited through local middle and high schools and through TRIO Upward Bound Math-Science programs nationwide. The students would perform better on the post-test survey than the pre-test survey, indicating the occurrence of learning and the one-direction t-test revealed that the improvement was statistically significant. The relationships between gender, grade, and the improvement on the content questions were analyzed using box plots. The male-identifying students had higher scores overall, but similar levels of improvement occurred for both male and female students. The 8–10th grade students improved the most among the various grade levels. The students reported enjoying the activity and having an increased interest in transportation engineering. Overall, the online survey with videos, games, and engagement questions proved to be an effective outreach method. These results shed light on the design of future outreach projects as the effects of the pandemic may last.

Keywords: outreach; recruitment; engineering curriculum; transportation

1. Introduction

1.1 Problem Statement

Workforce shortages in the transportation industry will put increased stress on transportation employees as they struggle to meet the demands of the nation's large transportation network [1, 2]. Newcomers to the field with a diverse background in multimodal transportation options and training in new technologies will be critical, as sustainable transportation solutions are given increased priority when making maintenance, operations, and expansion decisions [3]. Therefore, introducing young middle- and high-school students to transportation engineering concepts is necessary to engage them and inform their career decision-making, helping to fill this future known need [2]. By exposing students to the field of transportation engineering in interesting and educational ways, students will be more inclined to consider the field as they pursue further studies [4].

Extracurricular outreach events that introduce transportation engineering to students have been a proven method for increasing interest [5]. Developing a curriculum that is engaging, hands-on, and entertaining has the potential to influence students' thoughts about transportation engineering as a career. In this context, it is crucial for educators and researchers to understand and develop activities that motivate students to learn [5]. Outreach events allow for early exposure to the STEM (Science, Technology, Engineering and Mathematics) fields that students may not receive from school or their households if their parents are not working in the field [6]. Outreach activities are ideally performed face-to-face, but when COVID-19 resulted in a quarantine and inability to host an in-person outreach event in cooperation with local schools, the project was redesigned from a face-to-face event to an online format composed of instructional videos, online gaming, and questions that included a voluntary essay component. Research on exclusively online outreach events is limited, and this project thus provided an opportunity to gauge students' level of learning using the online platform.

Because of COVID-19, local Washington and Idaho schools had been teaching online while students quarantined at home in 2020. This led to a unique challenge to the transportation engineering outreach project, as students, according to some teachers, had "burned out" with their schoolwork and had not been completing school assignments. While eliciting participation in the project became a challenge, it also presented a new opportunity to

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reach a broader and more diverse audience. This proved to be an advantage as new outlets were discovered through federal TRIO Upward Bound Math Science programs nationwide, increasing participation in the project [7]. The outreach project also achieved a diverse and widespread respondent population, benefiting from the inherently diverse and nationwide nature of the Upward Bound Math Science Program, which is a federally funded program designed for low-income, first-generation, underrepresented students.

1.2 Goal and Objectives

The goal of this work was to engage middle and high school students in transportation engineering activities that include pre- and post- testing in order to assess their learning and the factors that influenced their learning. To meet this goal, the following objectives were addressed: (1) developing age-appropriate online transportation engineering activities, (2) packaging activities with complete instructions to allow students to access the project without assistance, (3) recruiting teachers and directors to encourage student participation, (4) assessing the data to determine student learning.

2. Literature Review

2.1 Importance of Outreach

STEM outreach events aim to expose students to STEM content, enabling them to become more confident, grow an interest, and eventually pursue a career in a STEM field. Students exposed to individuals in STEM careers or to college students studying STEM-related fields can more easily picture themselves in a STEM profession [8]. It is important to expose students to STEM content at a young age in order for them to develop an interest in a STEM career path later in life [5]. Outreach events provide this exposure in fun and engaging ways, but in order for the event to be successful, the activities and concepts must be of high interest to students, use realistic data to reflect real design considerations, should be self-contained, be completed within two hours, and should require active participation from the students [5]. Students may lose interest in the activity if it is too long, unrealistic, or involves only passive participation. For example, a successful outreach event occurred at a weeklong summer camp where female students participated in hands-on experiments, field trips, and interactions with female scientists [8]. Pre- and post-camp surveys showed drastic improvements in participants' attitudes toward the applicability of science, perceived level of support for scientific study, and interest in pursuing STEM related-careers [8]. Another summer camp emphasized the social context of engineering design and found that participants took more STEM courses and had higher STEM self-efficacy following the camp [9]. Outreach intervention has also found that many students do not have an understanding of what engineering is and outreach events that can correct misconceptions of the profession can increase student interest in the field [10]. Thus, exposing students to STEM content encourages them to explore more classes involving the content throughout their schooling and eventually pursue a career in STEM fields.

2.2 Online Outreach

Online outreach has proven to be an effective method for reaching a wide range of students from outside of one's own community [11]. With the COVID-19 pandemic, this type of outreach has become essential. The Chemical Engineering Department at the University of Utah developed a method of online outreach that increased their outreach participation from a mere 30 to over 3800 participants [11]. The department created 30 chemical engineering teaching and outreach modules on their website that allowed teachers to select a module, adjust the difficulty to best fit their classroom, and adapt the activity to match their goals [11]. Each module consisted of a list of materials and methods, procedures, learning outcomes, career connections, background and theory, instructional videos, and assessment questions [11]. With the content designed in a simple manner for teachers to access and use, they could easily add the module to their lesson plans [11]. Online outreach also can decrease the cost of performing outreach programs as fewer supplies typically need purchased [12]. Students do not need to be in a classroom to complete the outreach if the activity requires only a computer. Online programs can also incorporate multimodal learning easily, which is important as students learn best through a combination of sensory modalities [12]. Simulations can be used that mimic real-world environments that may not be able to be replicated in a traditional classroom, and electronic games allow students to have fun while learning new concepts [12]. Online outreach opens the door to many new opportunities that may not be accessible or utilized in a classroom setting.

2.3 Transportation Engineering Online Outreach

Many transportation engineering outreach programs have implemented online aspects, but few have created an entirely online outreach program [13]. One program integrated educational game modules and curricula to teach concepts of intelligent transportation control and management [13]. The interactive web-based traffic control simulation was introduced at high school summer camp sessions and the students indicated they were excited about the game and had more awareness of traffic engineering issues following their participation [13]. Other programs have provided resources to teachers that include online modules and presentations [14]. One program created a completely online build bridging contest and found that 95% of the participants, teachers, and engineers involved provided positive feedback [15]. Interactive online games can add a fun element to an outreach activity while still teaching students about the desired learning goals. There is a need for research on completely online transportation engineering outreach, particularly about its effectiveness [16].

2.4 Assessing Effectiveness of Outreach

Pre and post-surveys are often used to assess learning [17]. Pre and post-surveys can also allow the administrators to see where common weaknesses are and adapt materials accordingly after activities [17]. Pre and post-test surveys are effective in assessing learning and are commonly used in research measures [18].

3. National Survey of Middle and High School Students

3.1 Recruitment

Initially, 47 science teachers or principals at middle schools and high schools within a 60-mile radius of Pullman, Washington were emailed. Teachers were incentivized with a $50 gift card if they encouraged their students to participate. At this point, all schools had moved to online teaching because of COVID-19, so students were familiar with the virtual format. However, teachers expressed that students were not engaged in the classroom during this time. One teacher commented that her students had "checked out" of schoolwork.

Due to the online format, we were no longer bound to work only with local schools for participants and reached out to directors of TRIO Upward Bound Math-Science programs nationwide to encourage them to include the project into their summer program curriculum. Upward Bound Math-Science provides educational summer activities specifically for low-income, underrepresented, students and students with disabilities. The program has a long history of success and allowed the researchers to reach out to a more diverse population. We created a website and flyer for easy access to information, and for directors and teachers to post the flyer and/or forward the information to other interested educators. In addition, to increase participation, incentives were offered to students who completed the essay section of the survey.

Upward Bound Math-Science is one of several federally funded TRIO programs specifically designed to help strengthen skills in math and science and is offered to students who have high abilities in this area. Students who participate in the Upward Bound Math-Science program are typically first-generation college students, and the majority of students who complete the program go on to attend college. The students recruited from local high schools are of varying socioeconomic statuses and education levels of parents.

148 Upward Bound Math-Science directors in 35 states were emailed (Fig. 2). The contact information for each program was found online [19]. The sample size of complete surveys of 58 was well suited for the study as it provided a variety of participants from different backgrounds and places around the country. This provided a more accurate representation of students' results than a smaller, local sample size could have. Due to this, the results are likely transferable to a broader student population following the experiment.

3.2 Survey

Originally we planned face-to-face outreach events with middle and high school classrooms around the Pullman, Washington area to guide students through the outreach activity and administer pre and post-tests. Following the COVID-19 quarantine and the uncertainty that schools would reopen, we designed an online activity in Qualtrics that consisted of survey questions (see Appendix), a pre-activity test pertaining to the topic of transportation engineering, links to videos explaining what a transportation engineer does and how traffic signals work, an online transportation game, a post-activity test that was identical to the pre-activity test to gauge content recollection, and an optional short essay about the activity.

The pre-activity test, developed from the video content about transportation engineering as a career, highlighted the critical concepts and responsibilities of a transportation engineer. The seven-question multiple choice questionnaire was administered before and after the learning activities to gauge the level of learning with the online activities. Students were instructed to select the "I don't know" answer for a question instead of guessing if they did not know the answer to prevent students from correctly guessing. This allowed the researchers to assess what the participants knew and understood before and after the activity. The pre-activity and post-activity results were analyzed to find each student's level of improvement. The improvement was then compared with gender and grade level to analyze trends in the results.

The first video the students were instructed to watch was titled, "What does a transportation engineer do?" by Tonkin + Taylor on YouTube [20]. Tonkin + Taylor is an environmental and engineering consultant company in New Zealand. The video describes what a transportation engineer does on a day-to-day basis. The video is 2 minutes and 9 seconds in duration. This video was selected because it shows what a career in transportation engineering looks like and is short enough to keep students interested and rich with information on transportation engineering. The video was narrated by a Senior Transportation Engineer who works for Tonkin + Taylor. It was anticipated that the engineer's engaging personality may help students imagine themselves in a similar career. Following the video, participants were asked "What surprised you about a transportation engineer?" and "Was there anything that interested you?" to allow them to engage with the video content immediately and think about what they learned.

The second video was titled, "How Do Traffic Signals Work?" by Practical Engineering, which is a YouTube channel that teaches a variety of engineering topics for students [21]. The video is 12 minutes and 36 seconds in duration. The video begins by reminding students of the familiar concept of traffic and then elaborates on how traffic engineers control the flow of traffic in urban areas. Different types of traffic signals are explained and helpful graphics are shown to visually solidify concepts. This video was selected as it is informative, discusses how important the role of a transportation engineer is, and provides a deeper understanding of a situation that is likely familiar to most participants. For example, most everyone has sat at a traffic signal wondering why the light would not turn green. This video shows participants the science behind this common, real-world concern. Following this video, the participants were asked "What type of area do you live in?" with multiple choice options of rural and urban and "What surprised you about the video?" to engage the students with the video content immediately and encourage them to apply it to their lives.

The transportation game consisted of a series of levels that slowly increased in difficulty while the players guided vehicles from four directions through traffic signals [22]. While there were 15 levels available, the students were asked to play through only the first five to fit within the timeframe of the activity. There were easy, medium, and hard levels available, and the students were instructed to select the easy level. As shown in Fig. 1, the game consisted of an overhead view of a layout including traffic lights, multiple lanes of traffic, and crosswalks. The participant would click on a car to make it stop and click on it again to make it move when the timing was right. Participants had to decide when to stop traffic from one direction to let the other direction go. Some levels included crosswalks where pedestrians would cross the road at random intervals. If the participant caused two vehicles to crash, caused a traffic jam, or hit a pedestrian, they would have to restart the level. The game illustrated the challenge associated with creating traffic flow and coordinating traffic signals, allowing participants to gain a new understanding of one of the roles of a transportation engineer.

The final section of the activity asked students to write a short essay of no more than 300 words on what they learned in the activity. Students were told that by completing the voluntary essay, they would

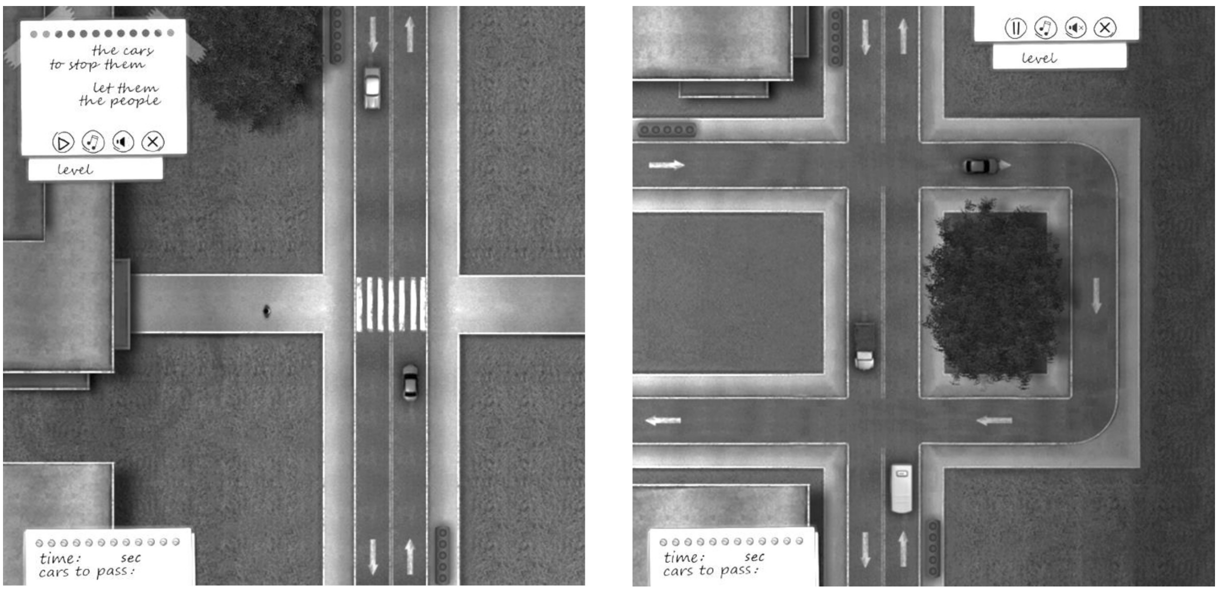

Fig. 1. Image of the first and third levels of the transportation game.

Fig. 2. State Upward Bound programs contacted for participation in the survey. Most states have more than one program; i.e. California has 16 programs throughout the state.

receive a certificate of completion from Washington State University and that the most thoughtful and quality essays would receive a distinguished certificate. Students were well informed that the essay activity was optional. This section of the activity enabled researchers to see how well the students understood the key concepts of the activity and to gauge the struggles students encountered during the project. One student shared in the essay, "In this activity, I learned the basics about the job of a traffic engineer and obtained a better idea of how traffic signals work. Traffic engineers are critical for the safety of everyone, while also helping us get to where we need efficiently. In the first video, the fact that traffic engineers need to use investigation analysis and design caught my interest."

3.3 Survey Analysis

The pre and post-test scores were analyzed in whole and on factors including gender and grade to determine what factors influenced the participants' improvement scores. Data was removed where the participants did not complete the entirety of the survey questions due to these students not accessing all of the content and materials provided in the survey, resulting in 58 complete responses that were analyzed. The overall pre and post-test scores were analyzed by first running a one-tailed t-test to determine if the improvement was significant between the scores from before the activity to after. A t-test is a way to compute the statistical significance of a parameter of a dataset, in terms of a test statistic that follows a student's t-distribution under the null hypothesis [23]. A p-value of less than 0.05 was considered significant. The scores were then separated into groups for gender and grade to determine what groups the activity was most effective at teaching. Box plots were created for the overall pre- and post-tests, as well as the gender and grade data to help visualize the improvement between the pre and post-tests. The essay portion of the survey was analyzed qualitatively and provided insights on whether the activity was enjoyable to the participants and if they felt they learned more about transportation engineering.

The gender of the participants was asked due to men having a stronger presence in the transportation engineering field and women feeling an identity threat when surround by men in STEM courses, making it increasingly important to engage women in outreach events [24]. The content and activities provided to students at an outreach event must be engaging for them to reap any benefits [5]. By analyzing the improvement scores of the different grade levels, it could be determined what grades this activity was suitable and effective for.

A series of other factors including self-efficacy, belongingness, time spent reading, time spent exercising, time spent using electronics, and time spent watching TV were measured in the survey to determine if there were noticeable relationships between pre- and post-test scores and the factors. The self-efficacy levels of the students were measured, as previous literature has reported that students with lower self-efficacy perform worse in the classroom [25]. We developed an academic self-efficacy survey to discover how the self-efficacy of the students influenced their ability to learn during the activity by adapting the Academic Self-Efficacy and Efficacy for Self-Regulated Learning Scale created from an adaptation of Zimmerman, Bandura, and Martinez-Pons' scale (1992) with Chemers, Hu, and Garcia's scale (2001) by Rudman (n.d.) and the Children's Self-Efficacy Scale created by Bandura [26, 27]. The two scales were combined to best incorporate the different aspects of self-efficacy and were shortened to fit better into the timeframe of the outreach activity.

The students' feelings of belongingness were measured, as previous research has indicated that higher belongingness in students is directly related to a stronger ability to learn [28]. We developed a belongingness survey to measure how the perception of belongingness of the students influenced their ability to learn in this activity. The survey was created by adapting the School Belongingness Scale developed by Arslan and Duru [29]. The original survey was shortened to better fit into the timeframe of the activity and some questions were reworded at the researchers' discretion to make them clearer to students.

The time students spent exercising daily was collected and compared to the pre and post-test content scores, as previous research has suggested that students who exercise more frequently perform better in the classroom [30–32]. We asked students how much they read daily and compared this to the pre and post-test content scores, as previous research has indicated that students who read more have a stronger ability to learn [33, 34]. The time students spent using electronics was collected and compared to the pre and post-test content scores due to previous research suggesting that electronic usage may lead to decreased academic performance [35]. The time students spent watching TV was collected and compared to the pre and post-test content scores, because previous literature has reported that students who watch more TV have increased difficulties learning in the classroom [36].

Correlations were conducted between the various factors, the pre and post-test scores, and the percent improvement. A value of 0.15 was considered significant due to the presence of multiple influential factors and the large scatter of level and age of participants.

3.4 Results of Qualitative Essay Analysis

All of the participants that completed the survey stated that they learned more about transportation engineering from the activity, with responses such as "I learned a lot more about transportation engineering (or rather, I learned just how much I didn't know about it) by doing this activity." Students were genuinely interested and enjoyed the activity as none of them reported it as being boring or not educational. Some responses reinforcing this were "Overall, this activity was very interesting and informing" and "I found this information to be quite interesting because I have always wondered whose job it is to design roads, crosswalks, and street signs." Some students became interested in a career as a transportation engineer, demonstrated by responses such as "The career of transportation engineers is fascinating," "Transportation engineering is a great career which is much more complicated than I thought," and "Though I was not interested at first, I think I might look into this topic in my free time." Many students reported a greater appreciation for transportation engineering and the people within the field with responses such as "I am glad I got to learn about what transportation engineers do and how they operate because from now on I will appreciate them more."

3.5 Results of Content-Based Pre and Post-Tests

3.5.1 Overall Scores

The overall pre and post-test scores were analyzed by first running a one-tailed t-test to determine if the improvement was significant between the scores from before the activity to after. The resulting p-value was significant ($p = 8.5859E-06$.)

A box plot was created to illustrate the distribution of the participants' scores in both the pre and post-tests. The minimum score increased from 0% in the pre-test to 28.6% in the post-test, the first quartile increased from 42.9% to 57.1%, the median value increased from 57.1% to 71.4%, the third quartile increased from 71.4% to 85.7%, and the maximum score was 100% for both the pre and post-tests. The distribution shifted upwards from the pre to post-test, illustrating that the scores improved after the activity (Fig. 3).

3.5.2 Gender

There were 39 female identifying participants, 18 male identifying participants, and 1 participant who selected the "other" option. Since only one student selected the nonbinary option, this piece of data could not be included in the gender analysis. The male first quartile increased from a score of 46.4% to 71.4%, the male median remained at

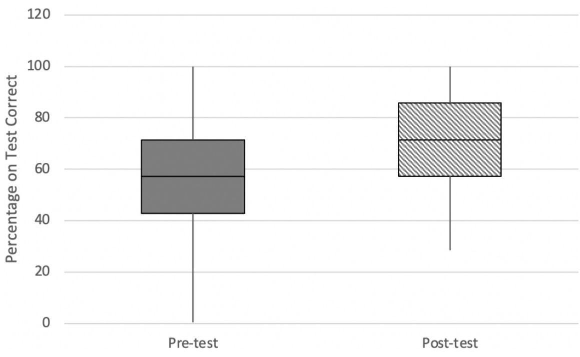

Fig. 3. Box plot of the overall pre and post-test scores for the content questions in the survey.

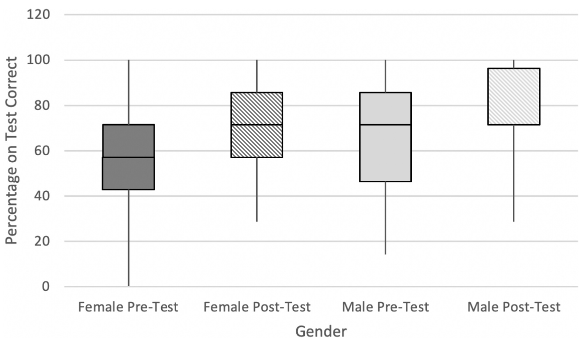

Fig. 4. Box plot of the pre and post-test scores for each gender for the content questions in the survey.

71.4% from the pre to post-test, the third quartile increased from 85.7% to 96.4%, and the maximum score for both was 100% (Fig. 4). The female minimum score increased from 0% to 28.6%, the first quartile increased from 42.9% to 57.1%, the median increased from 57.1% to 71.4%, the third quartile increased from 71.4% to 85.7%, and the maximum for both was 100% (Fig. 4). The male participants had overall higher pre and post-test scores than the female participants, but both groups improved from the pre to post-test.

3.5.3 Grade

The grades of the students were broken up into 3 groups containing 6 and 7th grades, 8th, 9th, and 10th grades, and 11th, 12th, and 13th grades, with 13th grade indicating the student was in the summer following their final year of high school. These groups were selected to indicate early middle school, late middle/early high school, and late high school. There were 30 participants in the 6–7th grade group, 18 students in the 8–10th grade group, and 10 participants in the 11-13th grade groups. The 6–7th grade group's minimum score increased from a 0% in the pre-test to a 28.6% in the post-test, the first quartile increased from 42.9% to 57.1%, the median value increase from 57.1% to 71.4%, and the third quartile remained at 85.7% and the maximum at 100% from the pre to post-tests (Fig. 5). The 8–10th grade group's minimum score increased from 14.3% to 42.9%, the first quartile increased from 42.9% to 57.1%, the median increased from 50% to 71.4%, the third quartile increased from 67.9% to 96.4%, and the maximum remained at 100% from the pre to post-test (Fig. 5). The 11–13th grade group's minimum remained at 42.9% from the pre to post-test, the first quartile increased from 60.7% to 71.4%, the median value increase from 71.4% to 78.6%, the third quartile increased from 82.1% to 85.7%, and the maximum remained at 100% (Fig. 5).

3.5.4 Other Factors

The average self-efficacy scores were compared to the pre and post-test scores on a box plot, as shown in Fig. 6. The box plot reveals that for every self-efficacy score, students improved in their understanding of the material presented. While the self-efficacy score range of 0.1 to 1 had the same median, third quartile, and maximum score, the minimum and first quartile increased, indicating this group still benefited from the activity.

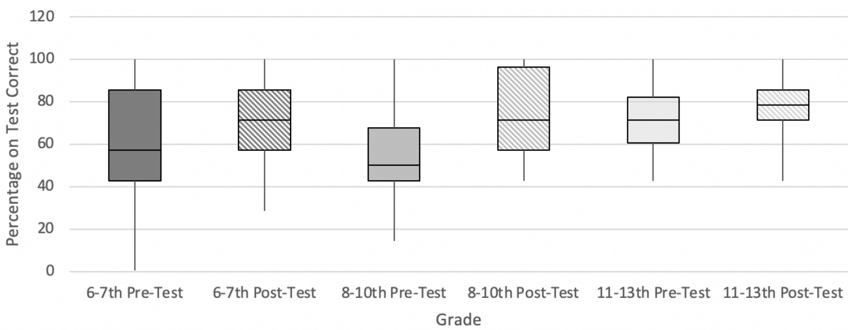

Fig. 5. Pre and post-test scores for the groups of different grades for the content questions in the survey.

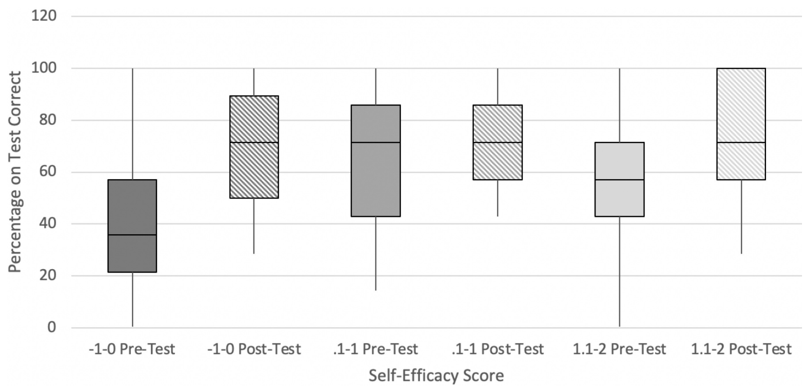

Fig. 6. Pre and post-test scores for the groups of different self-efficacy scores for the content questions in the survey.

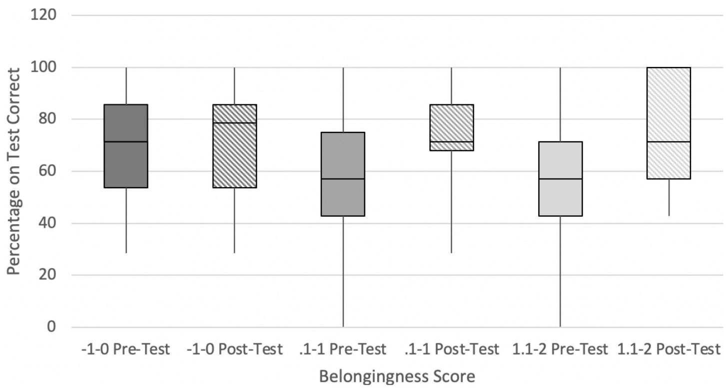

Fig. 7. Pre and post-test scores for the groups of different belongingness scores for the content questions in the survey.

Interestingly, students with higher belongingness scores had lower pre-test scores but higher post-test scores, as shown in Fig. 7.

Students at every level of this factor showed improvement from pre to post-test (Fig. 8). The highest two levels of exercise time showed the most improvement.

As the amount of time spent reading increased, so did both the pre and post-test scores for students (Fig. 9). The most improvement occurred in the lowest level of this factor, but improvement occurred in all levels.

While there is not a clear trend of the relationship between the levels of time spent using electronics and improvement, all of the levels show some improvement (Fig. 10). The lowest level of time spent using electronics had the same median, third quartile, and maximum, but the minimum and first quartile increased in the post-test.

A correlation of –0.35 was found between time spent reading and time spent using electronics which indicates the two are inversely related (Table 1). Time spent reading and self-efficacy had a correlation of 0.42 indicating a positive relationship. Time spent reading had positive correlation coefficients of 0.33 with pre-test percent and 0.28

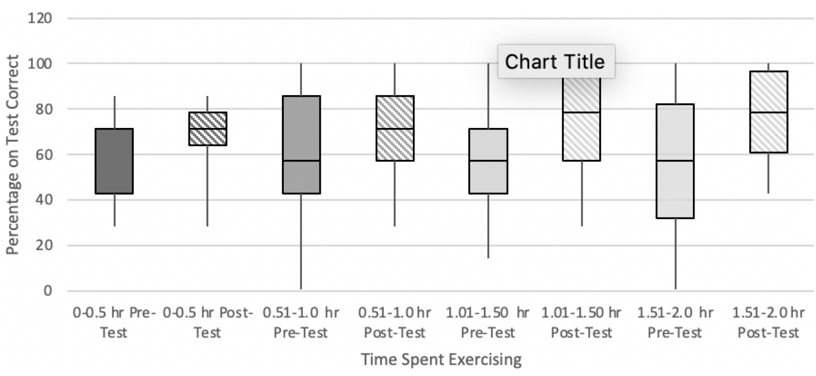

Fig. 8. Pre and post-test scores for the groups of different amounts of time spent exercising for the content questions in the survey.

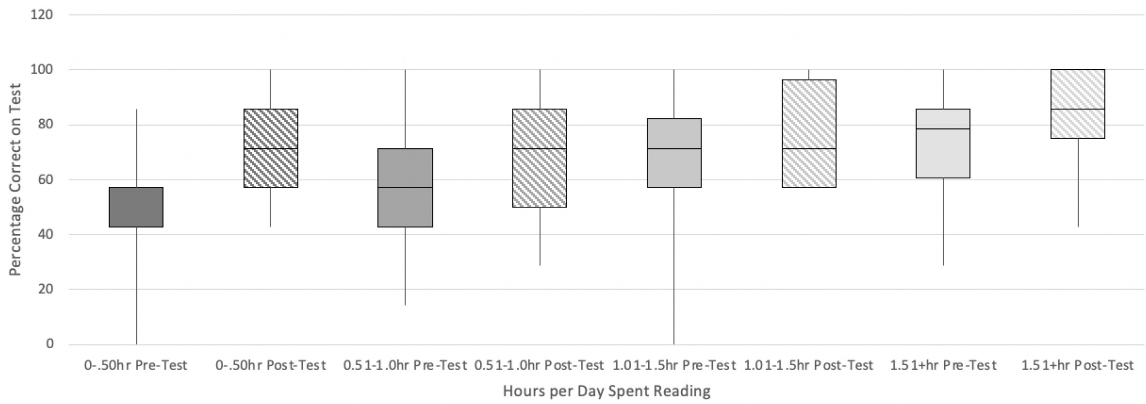

Fig. 9. Pre and post-test scores for the groups of different amounts of time spent reading for the content questions in the survey.

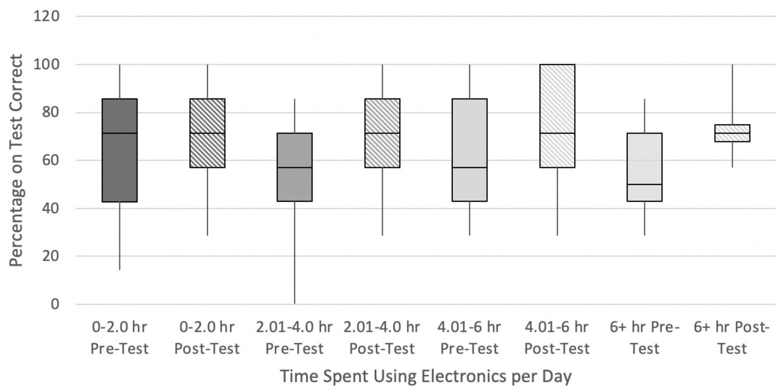

Fig. 10. Pre and post-test scores for the groups of time spent using electronics for the content questions in the survey.

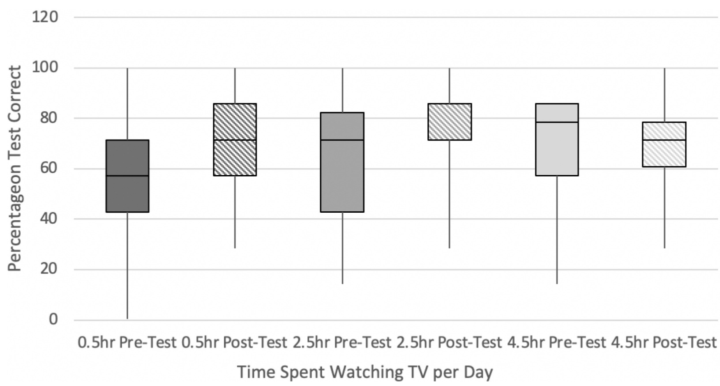

Fig. 11. Pre and post-test scores for the groups of different amounts of time spent watching TV for the content questions in the survey.

Table 1. The correlation coefficients found from comparing each of the factors discussed

	Time Watching TV	**Time Using Electronics**	**Time Exercising**	**Time Spent Reading**	**Self-Efficacy**	**Belonging-ness**	**Pre-Test Percent**	**Post-Test Percent**	**Percent Improve-ment**
Time Watching TV	1								
Time Using Electronics	–0.02	1							
Time Exercising	0.01	0.10	1						
Time Reading	0.02	**–0.35**	–0.15	1					
Self-Efficacy	–0.02	–0.14	–0.11	**0.42**	1				
Belongingness	0.11	–0.03	0.05	–0.06	**0.44**	1			
Pre-Test Percent	0.10	0.03	–0.07	**0.33**	0.09	–0.13	1		
Post-Test Percent	0.04	0.07	0.10	**0.28**	**0.18**	0.09	**0.55**	1	
Percent Improvement	–0.08	0.04	**0.17**	–0.11	0.06	**0.23**	**–0.60**	**0.33**	1

with post-test percent. Self-efficacy and belongingness had a positive correlation coefficient of 0.44. Self-efficacy and post-test percent had a weak positive correlation, with a correlation coefficient of 0.17. Belongingness and percent improvement had a correlation of 0.23. The pre and post-test percents had a correlation of 0.55. The pre-test percent and percent improvement had a correlation of -0.60 suggesting that the students who performed better on the pre-test did not improve as much as those who scored lower on the pre-test. The post-test percent and the percent improvement had a correlation of 0.33 indicating that the students who improved more had higher post-test scores.

4. Discussion

By understanding the effectiveness of this outreach activity overall and for the various groups that were analyzed, we can understand who benefitted from this activity and if it should be modified to better include groups that did not show improvement in knowledge from before to after the activity. Since a p-value of less than 0.05 on a one-tailed t-test indicates a significant change in a single direction, the small p-value for the overall scores indicates that the improvement was significant and that the students learned from the activity. This suggests that overall, this activity was effective in teaching the students about transportation engineering. Additionally, the essay portion of the activity provided insight that the students enjoyed the activity as well.

The positive correlation between pre and post-test percentages indicates that the students who performed better on the pre-test also performed better on the post-test. The negative correlation between pre-test percent and percent improvement suggests that the students who performed better on the pre-test did not improve as much as those who scored lower on the pre-test. This was likely due to the students having less room for growth if they reached the ceiling of scores.

When breaking down the results by gender, we observed that the male participants had overall higher pre and post-test scores than the female participants, but both groups improved from the pre to post-test. This observed difference could be due to stereotype threat as the female students may have been afraid that performing poorly would have reinforced the stereotype that female students are not as successful in STEM as male counterparts, resulting in extra stress that can cause poor performance [37, 38]. When analyzing the scores by grade level, the most significant improvement from pre to post-test scores occurred with the 8–10th grade group as each of their quartiles shifted upwards greatly from the pre to post-test scores. The oldest group, 11–13th graders, had the least improvement. This could be due to the level of the content as it was created to be comprehendible to students as young as 6th grade, resulting in the 11–13th grade group being less engaged. However, they did not reflect this in their essay responses. This level of content and mode of delivery may have been the ideal for the 8–10th grade group as this is where the greatest growth occurred.

Time spent reading had positive correlations with pre-test percent and post-test percent, indicating that the amount a child reads could be related to their knowledge coming into an activity and what they can learn during the activity. When observing the box plot for time spent reading, a clear upward trend can be seen in the scores of the students as the time spent reading increased. This supports findings in previous literature that increased reading is related to a student's ability to learn [39, 40]. Time spent reading and self-efficacy had a positive correlation, indicating that those who read more had higher self-efficacies than those who read less.

Time spent exercising had a weak positive correlation with percent improvement. It was also observed that students who were clumped into the highest two levels of time spent exercising, showed greater improvement in the content question scores than the lower levels. This may indicate that more time spent exercising can relate to higher abilities to learn, a concept that has been illustrated in many studies [30–32].

Neither time spent using electronics nor time spent watching TV indicated a significant relationship to content scores or improvement in the activity in the correlational analysis or when analyzing the box plots of the data (Fig. 11). This contradicts previous literature that suggests that use of electronics can result in lower learning capabilities of students [35].

Self-efficacy and post-test percent had a weak positive correlation, indicating that the amount of self-efficacy a child has may be loosely related to their ability to learn content in the online transportation engineering outreach activity. This finding weakly supports previous findings that self-efficacy and academic performance were correlated [25].

Students with higher belongingness scores improved more from pre- to post-test than those with lower belongingness scores, as observed in the box plot of belonginess scores. In addition to this, the weak positive correlation between belongingness and percent improvement may suggest that there is a relationship between belongingness and ability to learn information in online outreach activities. These findings support previous literature that has found that students with higher levels of belongingness had a greater capacity for learning [28].

Limitations for this study include that when the survey was being distributed, students were nearing their summer breaks in school. This may have caused students to be less motivated to complete the activity and made it more difficult to recruit participants. One teacher even told the researchers that students were not even completing their classwork since everything moved to a virtual format due to COVID-19. However, the online format allowed for students from around the country to be recruited. Another limitation was that the same content was used for grades 6-13th and this could have resulted in the content being too easy for the oldest students or too challenging for the youngest students. It is possible that the environments the participants were in may have influenced the results of the data as their environments could not be controlled. While every participant completed the same online outreach activity, they were each in a unique home setting. While this is expected of online outreach events that occur outside of classroom setting, it is a factor that should be considered. An additional limitation is that not all students completed the survey. While only complete surveys were analyzed, future studies could analyze reasons why students may not complete a study to determine how to further improve outreach surveys and activities.

This work explored the feasibility of conducting a completely online outreach event. The project explored methods of recruiting participants and engaging students in this new online format. Online outreach events should continue to be explored due to the rapidly changing technology available to students. The best methods for distributing and encouraging participation for online outreach should be further explored. Due to only one participant identifying as "other" in the gender category, only the improvement of male and female identifying students could be compared. A study with an increased number of non-binary students would allow for further research into the influence of gender on ability to learn from this format of outreach activity. The discrepancy found between male and female students should be further explored as it should be a goal for this gender difference to be eliminated. Future research could also incorporate finding ways to make the activities culturally relevant to the specific locations of the students as previous literature as shown this can help the students gain an interest in engineering [41].

The data overall agrees that improvement occurred for children across all factors. No groups of students were left behind due to factors that could inhibit their ability to learn. This indicates that the online survey method of providing outreach can be effective for all students in middle and high school.

5. Conclusions

The following findings were based on the analysis of the 58 usable survey responses after the incomplete surveys were removed.

- The activity resulted in significant learning of transportation engineering topics in the participants.
- Male identifying students scored higher on the pre and post-tests than female identifying students did, but the improvement was similar for both genders.
- For the grade of participants, the most improvement occurred in the 8-10th grade group, but improvement occurred in all groups.
- Overall, the online survey utilizing videos, games, and engagement questions was an effective method of outreach.

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Appendix: Survey Instrument

Survey questions

Non-Content Based Questions for Middle and High School

Understanding Population:

1. How old are you?
2. What grade are you in?
3. What gender are you?

Factors:
How much time do you spend. . .

1. . . . watching TV per day?
   a. 0–1 hour
   b. 2–3 hours
   c. 4–5 hours
   d. 6+ hours
2. . . . using electronics (cell phone, iPad, etc.) per day?
   a. 0–1 hour
   b. 2–3 hours
   c. 4–5 hours
   d. 6+ hours
3. exercising per day?
   a. 0–1/2 hour
   b. 1/2–1 hour
   c. 1–2 hours
   d. 2+ hours
4. reading per day?
   a. 0–1/2 hour
   b. 1/2–1 hour
   c. 1–2 hours
   d. 2+ hours

Stigmas:

1. What do you think a scientist looks like?
2. What do you think makes a good scientist?
3. Who can become a scientist?

Academic Self-Efficacy (Q14 on survey):

1. I can finish homework assignments by deadlines.
   a. Very untrue
   b. Somewhat untrue
   c. Unsure
   d. Somewhat true
   e. Very true
2. I can study when there are other interesting things to do.
   a. Very untrue
   b. Somewhat untrue
   c. Unsure
   d. Somewhat true
   e. Very true
3. I can take good notes in class.
   a. Very untrue
   b. Somewhat untrue
   c. Unsure
   d. Somewhat true
   e. Very true
4. I can succeed on tests.
   a. Very untrue
   b. Somewhat untrue
   c. Unsure
   d. Somewhat true
   e. Very true
5. I can ask questions in class.
   a. Very untrue
   b. Somewhat untrue
   c. Unsure
   d. Somewhat true
   e. Very true
6. I am good at writing papers.
   a. Very untrue
   b. Somewhat untrue
   c. Unsure
   d. Somewhat true
   e. Very true
7. I am a very good student.
   a. Very untrue
   b. Somewhat untrue
   c. Unsure
   d. Somewhat true
   e. Very true
8. I usually do very well in school and at academic tasks.
   a. Very untrue
   b. Somewhat untrue
   c. Unsure
   d. Somewhat true
   e. Very true
9. I find my academic work interesting and absorbing.
   a. Very untrue
   b. Somewhat untrue
   c. Unsure
   d. Somewhat true
   e. Very true
10. I am very capable of succeeding.
   a. Very untrue
   b. Somewhat untrue
   c. Unsure
   d. Somewhat true
   e. Very true

Belongingness (Q15 on survey):

1. I can be myself at school.
   a. Almost never
   b. Sometimes
   c. Often
   d. Almost always
2. I feel like I don't belong at school.
   a. Almost never
   b. Sometimes
   c. Often
   d. Almost always
3. I have close relationships with my teachers and friends.
   a. Almost never
   b. Sometimes
   c. Often
   d. Almost always
4. I think that I am not involved in many activities at school.
   a. Almost never
   b. Sometimes

   c. Often
   d. Almost always
5. I feel myself excluded at school.
   a. Almost never
   b. Sometimes
   c. Often
   d. Almost always
6. I see myself as part of this school.
   a. Almost never
   b. Sometimes
   c. Often
   d. Almost always
7. I think people care about me at school.
   a. Almost never
   b. Sometimes
   c. Often
   d. Almost always

Content Based Questions for Middle School and High School Students

Questions from information in: https://www.youtube.com/watch?v=DP62ogEZgkI

1. What is a traffic signal?
   a. *Electric traffic control device*
   b. The people who control traffic
   c. Cars at intersections
   d. A stop sign
   e. I don't know
2. What is an actuated signal?
   a. *A traffic signal activated by vehicles or pedestrians*
   b. A stop sign
   c. A traffic signal that has fixed cycles lengths
   d. Any traffic light
   e. I don't know
3. What is signal coordination?
   a. A button allowing pedestrians to activate the light
   b. *Traffic signals that connect with each other to optimize traffic flow*
   c. A traffic signal that has fixed cycle lengths
   d. A signal activated by a vehicle
   e. I don't know
4. What is a phase?
   a. *The amount of time a signal is a certain color*
   b. The area where a traffic signal is
   c. A city where a traffic signal is
   d. The number of cars that pass through a traffic signal
   e. I don't know
5. What is a traffic signal controller?
   a. *A box that is used to reprogram signals*
   b. A person who controls a traffic signal
   c. The button we press at a crosswalk
   d. The cars at a traffic signal
   e. I don't know
6. What is an urban area?
   a. *A highly populated area or city*
   b. A sparsely populated area or farmland
   c. A place where not many people drive
   d. A forested area
   e. I don't know
7. What is a rural area?
   a. *A sparsely populated area, farmland*
   b. A highly populated area, city
   c. A place with a lot of houses
   d. A place where people drive frequently
   e. I don't know

Video Related Questions

After this video: https://www.youtube.com/watch?v=ksTY7JeT78w

1. What surprised you about a transportation engineer?
2. Was there anything that interested you?

After this video: https://www.youtube.com/watch?v=DP62ogEZgkI

1. What type of area do you live in?
   a. Urban
   b. Rural
2. What surprised you about the video?

Olivia Willis graduated from Washington State University in 2022 with bachelor's degrees in both Neuroscience and Psychology and minors in French and Biology. While attending WSU, she participated in undergraduate research across different disciplines, ranging from psychology and neuroscience to transportation engineering. Olivia is passionate about understanding different aspects of human life, including development, learning, and addiction. She plans on attending medical school in the near future.

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