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Studying the Impact of a Residential Program on High School Students' Interest in Transportation Engineering (Evaluation)

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Studying the Impact of a Residential Program on High School Students' Interest in Transportation Engineering

Abstract

The National Summer Transportation Institute (NSTI) was a week-long summer residential program supported by the Federal Highway Administration, the state's Department of Transportation, and a college of engineering in a large university. The program engaged participants in transportation engineering topics with opportunities to interact with engineers who plan and maintain transportation systems. 125 students entering grades 10-12 spent one week living at the university campus. Students participated in tours of transportation-related sites not normally accessible to the public including traffic management centers, airports, and active construction sites. Students also engaged with faculty and toured campus labs related to aviation, structures, and materials. Students were mentored by undergraduate engineering students. Students were asked to read a set of transportation engineering problems and identify whether they were good examples of transportation engineering and how appealing these examples were to enhance their interest in these types of problems. The study found that through a rich set of immersive transportation engineering experiences, statistically significant increases in awareness of- and interest in- transportation engineering could be engendered in high school students.

Introduction

As a comprehensive research-intensive public university with one of the country's largest engineering degree granting programs from the Baccalaureate to the PhD, Arizona State University aims to engage the next generation of engineers and problem solvers in thinking about the future, the types of problems they wish to solve, and enhance their awareness and interest in engineering as a career. The Ira A. Fulton Schools of Engineering offers a variety of experiences to K-12 students that range from campus visits to week-long summer programs. Programs are thematic and help students explore problems that can be addressed through engineering. Thus, when the National Summer Transportation Institute opportunity became available, we pursued the funding opportunity to design and offer experiences to high school youth who can explore how engineering and its many disciplines offer career paths where they can make significant contributions to society through the transportation industry (NAS 2014, 2018).

The National Summer Transportation Institute (NSTI) was authorized by Congress under Section 1208 of the Transportation Equity Act for the 21st Century as a Transportation Career Education Program for Secondary School Youth. The NSTI is one of many educational initiatives established by the United States Department of Transportation (USDOT) and the Federal Highway Administration (FHWA). The goal is to address the need for a diverse workforce and to create an awareness of the career choices and opportunities that exist in the transportation industry. Because the role of transportation networks in society and the economy is not always obvious to youth, the NSTI program aims to spark interest in high school youth through a week-long residential program that gives participants an immersive set of field experiences to explore transportation engineering topics.

We need future transportation engineers who can identify the ways in which the transportation infrastructure can be examined and understood thereby leading to sustainable solutions. Capacity, condition, funding, future need, operation and maintenance, public safety, resilience, and innovation of our transportation industry are worthy of attention (ASCE, 2021). Thus, we deliberately set about designing and delivering an experiential set of opportunities that many high school students wouldn't typically have access to otherwise. The transportation engineering experiences (Ivey, Golias, et al., 2012; Kianfar & Belt, 2020) we wanted our high school participants to explore included experiencing for themselves a variety of transportation modes (metro bus, chartered bus, light rail, sky-train from designated areas to international airport), transportation management systems (department of transportation, metro bus/rail traffic center, highway management, aviation/airport management), construction and safety (asphalt lab, aviation and flight simulation training, airport maintenance and safety management, road/high way construction and management), and city/state transportation professionals. Interacting with a variety of professionals involved in the transportation industry along with "behind the scenes" experiences at a large international airport and as well as the reliever airport for the larger one and interactive presentations with experts about how the airport is governed and managed should help demystify the role airports play transportation systems.

Hence, the research questions were designed to elicit any changes in students' awareness of- and interest in- transportation engineering problems that they were likely to learn through the NSTI program experience. We identified ten transportation engineering examples that represent the issues worthy of attention (ASCE, 2021) and were directly related to program experiences. Research questions addressed in the paper are focused on understanding participants' perceptions about transportation engineering.
Q1. Are specific transportation related problems good examples of engineering?
Q2. How appealing are specific examples of transportation engineering that they evoke interest in participants?

Participants

This particular NSTI program targeted high school students entering grades 10-12 in the subsequent Fall semester. Participants were from 70 different high school campuses across the state, with one school sending 16 students. There was no cost to attend the residential program. Participants were admitted into the program on a rolling basis.

Our recruitment efforts targeted populations from rural and urban neighborhoods and also those typically underrepresented in STEM fields. Participation from across the state, including rural and Title I schools was sought. 180 applications were received. Selection was based on a review of high school transcript for academic performance, a recommendation letter from a STEM teacher, transcripts, and stated interest in exploring transportation engineering careers in an application essay. Of the 128 participants accepted to the NSTI program, 123 attended. As a part of the application process, the program collected demographics (see Tables 1, 2, and 3) and related measures such as self-reported enrollment in free and reduced-price lunch program and first-generation status based on parent/guardian education level.

Table 1. Participant demographics by Sex and Race/Ethnicity

	Number	Percent
Total Number of Participants	**123**	
Sex		
Female	42	34.1%
Male	81	65.9%
Race/Ethnicity		
Under-represented Minorities (URM)	40	32.5%
American Indian or Alaska Native	2	1.6%
Black or African American	7	5.7%
Hispanic or Latino	31	25.2%
Asian	19	15.4%
White	56	45.5%
Multiple races	6	4.9%
Other	2	1.6%

Table 2. Participant demographics by other indicators

	Number	Percent
Total Number of Participants	**123**	
Free and Reduced-Price lunch enrollment	41	33.3%
Lived in a rural area	31	25.2%
First-generation to college	37	30.1%
Neither parent an engineer	92	74.8%
Parent works in the Construction Industry	30	24.4%

Table 3. Participant demographics by grade level

	Number	Percent
Total Number of Participants	**123**	
Grade 10	50	40.7%
Grade 11	43	35.0%
Grade 12	30	24.4%

The NSTI Experience

Many of these NSTI participants had never visited a university campus, let alone experienced campus life by living in a university dorm for a week. Therefore, we aimed to create a lived-experience for a diverse set of students from across the state who would have the opportunity explore what it is like to live on a university campus. We worked with the student life center to provide participants with access to the swimming pool, gym, basketball courts, and other group fitness areas. In addition, we employed undergraduate engineering students (Nambisan, Alleman, Larson, & Grogg, 2014) as mentors—day and evening/night counselors—who interacted with participants to support students during the program and also informally interact with and share their own personal journey of how they navigated becoming an engineering student.

The program experience was offered four times, each time as a week-long experience. We had accepted 32 students for each week for a total of 128 participants. However, due to last minute cancellations and no-shows, we had 123 participants who completed the week-long program. The NSTI experience was developed by a collaborative of transportation and construction industry professionals and university faculty, high school educators, university engineering education and recruitment staff, and K-12 educators who are on university staff as engineering educators (Sanford-Bernhardt, Hurwitz, Young, et al., 2013).

Sunday: Families dropped off their students at the university campus dorm on Sunday and the program started that evening at 5 pm with an orientation for the participants. At orientation, program participation norms were emphasized (continuation from email communication during acceptance and parental permission). Participants were introduced to each other and to their undergraduate student mentors. Following dinner, students had ice-breaker and team building activities.

Monday: Field trips to a light rail extension site, city traffic management center, and state department of transportation traffic management center.

Tuesday: Field trip to the university's bridge design lab, asphalt lab, and interactive meetings with a team of university students who were competing in a national transportation challenge to design a future transportation technology such as Hyperloop.

Wednesday: Field trip to the international airport and interaction with various airport teams—fire station and safety, airport management, construction and maintenance, and air traffic control.

Thursday: Field trip to suburban airport; interactions with city construction-in-progress teams (engineers, managers) and city leaders (councilman) and staff.

Friday: Field trip to university's aviation and flight control center adjacent to the suburban airport. Final presentations and check out.

Each day, students had classroom time to work in small teams and individually. The aim of these classroom sessions was to help participants reflect on their transportation related experiences and interactions with experts to further develop and articulate their understanding of local transportation and construction industry and related careers (West, 2018). All meals, breakfast, lunch, and dinner, and snacks were provided.

Data Collection and Methods

A pre-post survey was developed (NAE, 2008, 2013) to elicit the following data: 1) the types of problems participants thought were good (or not good) examples of transportation engineering; and 2) transportation engineering examples they considered to be personally appealing to them (not at all appealing to very appealing) to answer two research questions. Matched-pair data were cleaned and organized to be analyzed using a statistical analysis software (IBM Corporation, 2020). The Wilcoxon signed-rank test, a non-parametric statistical hypothesis method (Coder & Foreman, 2009; Conover, 1999; Hollander, Wolfe, & Chicken, 2014), was used to compare the matched paired data (see Tables 4 and 5). Effect sizes (Lenhard & Lenhard, 2016; Palij, 2015) were calculated to identify changes in post vs pre as small, moderate, medium, and large.

Q1. Are specific problems good examples of engineering? Participants were presented with ten transportation related problems pre and post program and asked to identify if the problem was a good or not good example of engineering. The intent here was to understand whether students considered key transportation related challenges as good engineering examples. The problems were chosen based on ideas that were addressed throughout the NSTI program experience—field trips and expert presentations. These problems represent a range of transportation engineering topics that are worthy of attention (ASCE, 2021). They are related to capacity, condition, funding, future need, operation and maintenance, public safety, resilience, and innovation of our transportation industry and systems.

Q2. How appealing are specific examples of transportation engineering that they evoke interest in participants? Participants were presented with the same ten transportation engineering related problems as in the previous question, pre and post program. However, this time around they were asked to rate on a scale of Not appealing at all to Very appealing, with the question, "Does this example create interest in you?" As students learned more about transportation engineering, we hoped to learn whether these types of challenges were appealing enough to evoke interest in these challenges. If students express that they find these problems appealing, then they are more likely to explore these topics in the future.

Table 4. Wilcoxon Signed-Rank Test results for Research Question 1

Transportation Engineering Problem	**Standard Test Statistic** *z*	**Sig** ***P***	**Decision**	**N**	**Effect Size** ***R***
1. Creating a system for tracking aircraft	1.387	0.166	Retain	114	0.1299
2. Designing bridges that withstand earthquakes	1.291	0.197	Retain	115	0.1203
3. Mapping best location for water main pipes	5.657	0.000	**Reject**	114	**0.5298**[c]
4. Developing the world's fastest plane	2.524	0.012	Reject	114	0.2364[a]
5. Evaluating safety of road conditions on highways	6.337	0.000	**Reject**	115	**0.5909**[c]
6. Construct a scale model of newly proposed airport	1.789	0.074	Retain	115	0.1668
7. Developing a computer program to monitor traffic flow	1.500	0.134	Retain	114	0.1405
8. Assessing optimal routes for emergency vehicles	6.193	0.000	**Reject**	114	**0.5800**[c]
9. Diagnose potential failure points in airport runways	5.520	0.000	**Reject**	114	**0.5170**[c]
10. Creating software to control traffic signals	5.427	0.000	**Reject**	112	**0.5128**[c]

[a.] Small effect size

[c.] Medium effect size

Table 5. Wilcoxon Signed-Rank Test results for Research Question 2

Transportation Engineering Problem	Standard Test Statistic *z*	Sig *P*	Decision	N	Effect Size *R*
1. Creating a system for tracking aircraft	2.364	0.180	Reject	111	0.2244[a]
2. Designing bridges that withstand earthquakes	0.261	0.794	Retain	110	0.0249
3. Mapping best location for water main pipes	5.969	0.003	**Reject**	108	**0.5744**[c]
4. Developing the world's fastest plane	4.614	0.000	Reject	110	0.4399[c]
5. Evaluating safety of road conditions on highways	6.679	0.000	**Reject**	111	**0.6339**[c]
6. Construct a scale model of newly proposed airport	4.068	0.000	Reject	108	0.3914[b]
7. Developing a computer program to monitor traffic flow	1.158	0.247	Retain	114	0.1085
8. Assessing optimal routes for emergency vehicles	6.998	0.001	**Reject**	110	**0.6672**[c]
9. Diagnose potential failure points in airport runways	6.056	0.000	**Reject**	114	**0.5671**[c]
10. Creating software to control traffic signals	5.925	0.000	**Reject**	113	**0.5573**[c]

[a.] Small effect size
[b.] Moderate effect size
[c.] Medium effect size

Findings and Discussion

These results indicate that field-based transportation engineering experiences and interactions with engineers and engineering faculty and students can prompt changes in participants' understanding of- and interest in- transportation engineering-related fields. We used the Wilcoxon signed-rank test to test the "null hypothesis" whether the distribution of the median differences between pre and post paired samples is symmetric about zero. The goal of the test is to determine if the pre post pairs are different from one another in a statistically significant manner. In tables 4 and 5, the "Sig." column indicates the p-value. If the p-value is < 0.05, then it is significant. The "Decision" column is based on the p-value. If the decision is to reject the null hypothesis, then the result indicates that there are statistically significant differences pre-post program. If the decision is to retain the null hypothesis, then there are no statistically significant differences between pre and post program. The effect size (Kerby, 2014) helps us with the interpretation of the importance of the result in comparison to the statistical significance. The effect size was calculated by dividing the Standardized test statistic z by the square root of the number of pairs. According to Cohen's classification of effect sizes, effect sizes are classified as follows: 0.1 and above but below 0.3 = small effect; 0.3 and above but below 0.5 = moderate effect; 0.5 and above but below 0.8 = medium effect; and 0.8 and above = large effect size.

Do NSTI participants post-program demonstrate increased awareness that transportation engineering problems are good examples of engineering? (See Table 4).

A Wilcoxon signed rank test revealed a statistically significant difference in the pre and post responses of NSTI participants as follows.
<u>Medium Effect Size</u>
Post program, $n = 114$, $Z = 5.657$, $p < 0.05$, with medium effect size of 0.5298, participants demonstrated enhanced awareness of "#3. Mapping best location for water main pipes" as a problem that can be solved with engineering.
Post program, $n = 115$, $Z = 6.337$, $p < 0.05$, with medium effect size of 0.5909, participants demonstrated enhanced awareness of "#5. Evaluating safety of road conditions on highways" as a problem that can be solved with engineering.
Post program, $n = 114$, $Z = 6.193$, $p < 0.05$, with medium effect size of 0.5800, participants demonstrated enhanced awareness of "#8. Assessing optimal routes for emergency vehicles" as a problem that can be solved with engineering.
Post program, $n = 114$, $Z = 5.520$, $p < 0.05$, with medium effect size of 0.5170, participants demonstrated enhanced awareness of "#9. Diagnose potential failure points in airport runways" as a problem that can be solved with engineering.
Post program, $n = 112$, $Z = 5.427$, $p < 0.05$, with medium effect size of 0.5128, participants demonstrated enhanced awareness of "#10. Creating software to control traffic signals" as a problem that can be solved with engineering.

Do NSTI participants post-program demonstrate increased interest in transportation engineering problems? (See Table 5).

A Wilcoxon signed rank test revealed a statistically significant difference in the pre and post responses of NSTI participants as follows.
<u>Small Effect Size</u>
Post program, $n = 111$, $Z = 2.364$, $p = 0.180$, with small effect size of 0.2244, participants demonstrated enhanced interest in "#1. Creating a system for tracking aircraft".

<u>Moderate Effect Size</u>
Post program, $n = 110$, $Z = 4.614$, $p < 0.05$, with moderate effect size of 0.4399, participants demonstrated enhanced interest in "#4. Developing the worlds fastest plane".
Post program, $n = 108$, $Z = 4.068$, $p < 0.05$, with moderate effect size of 0.3914, participants demonstrated enhanced interest in "#6. Construct a scale model of newly proposed airport".

<u>Medium Effect Size</u>
Post program, $n = 108$, $Z = 5.969$, $p < 0.05$, with medium effect size of 0.5744, participants demonstrated enhanced interest in "#3. Mapping best location for water main pipes".
Post program, $n = 111$, $Z = 6.679$, $p < 0.05$, with medium effect size of 0.6339, participants demonstrated enhanced interest in "#5. Evaluating safety of road conditions on highways".
Post program, $n = 110$, $Z = 6.998$, $p < 0.05$, with medium effect size of 0.6672, participants demonstrated enhanced interest in "#8. Assessing optimal routes for emergency vehicles".
Post program, $n = 114$, $Z = 6.056$, $p < 0.05$, with medium effect size of 0.5672, participants demonstrated enhanced interest in "#9. Diagnose potential failure points in airport runways".

Post program, $n = 113$, $Z = 5.925$, $p < 0.05$, with medium effect size of 0.5574, participants demonstrated enhanced interest in "#10. Creating software to control traffic signals".

Statistically significant results (Conover, 1999; Wilcoxon, 1945) showed (see Table 4) that students learned that transportation related problems such as (#3) mapping best location for water main pipes, (#5) evaluating safety of road conditions on highways, (#8) assessing optimal routes for emergency vehicles, (#9) diagnose potential failure points in airport runways, and (#10) creating software to control traffic signals were good examples of engineering. Similarly, participants also found these same problems to be appealing (see Table 5). The effect size (Kerby, 2014) of the change in participants' perceptions about the relevance of these transportation engineering related problems pre to post program were mat the medium level. This is an indicator that the post program results differed by at least 0.5 standard deviations or more. This is a significant learning gain in an informal learning experience such as the NSTI which was of a week-long duration. During this week-long program, participants had immersive experiences with access to experts and dedicated time for facilitated small group interactions led by peer mentors. Students had multiple opportunities to explore these transportation related topics via site visits and interactions with professionals at the international and reliver-suburban airports (#9 diagnose potential failure points in airport runways); visit to city management center and interactions with city water and infrastructure management professionals and leaders (#3 mapping best location for water main pipes); visits to state department of transportation and city transportation center and interactions with professionals (#5 evaluating safety of road conditions on highways, #8 assessing optimal routes for emergency vehicles, and #10 creating software to control traffic signals). In some of these field-trips participants were able to see the large interactive displays and experience first-hand how software is used to manage traffic across various transportation systems.

Furthermore, 40.7% of the participants included rising sophomores who needed more direct and relevant experiences to understand the role of software engineers in creating systems to track aircraft and monitoring traffic flow. Also, in order to expand students' knowledge of how bridges may behave during earthquakes the bridge design lab will be modified for future programs to include a specific module on features of bridge design and use of specific materials that have an impact of stability and resilience.

We did not notice significant change related to problem #6—construct a scale model of newly proposed airport. Modeling is an abstract activity. Often modeling is misunderstood to be a mere physical replica of the real object. Understanding the role that modeling plays in engineering design is not trivial. Students need experiences to gain the understanding that explanatory models are integral to the engineering design process. These types of models help predict and understand anticipated system behaviors (NAS, 2017; NRC, 2011). Because computer aided tools are used to develop these models, students need more opportunities with these tools to create engineering models. In future programs, we plan to incorporate an explanatory modeling activity using a computer aided tool such as Autodesk Fusion 360 scale model as a demonstration.

Conclusion

It is important for students to understand the complexity of familiar aspects of transportation. This importance is underscored by the work of the ASCE Committee on America's Infrastructure. In its 2021 report card, this committee gave US Infrastructure an overall grade of C- (Mediocre, requires attention). They used the following criteria: a) capacity, b) condition, c) funding, d) future need, e) operation and maintenance, f) public safety, g) resilience, and h) innovation (ASCE, 2021). These criteria represent a systems view of transportation. We need future transportation engineers to develop these viewpoints to ensure a sustainable transportation infrastructure for all. However, developing understanding of transportation engineering issues and acquiring expertise requires long-term engagement including education pathways in undergraduate education and beyond. Arizona State University offers a wide range of short- and long-term experiences to help high school youth explore engineering and make informed choices about their higher education pathways. NSTI participants will be made aware of these opportunities. NSTI participants are encouraged take advantage of these opportunities to explore and expand their perspectives about problems that are worth solving so quality of life can be improved for all. The brief week-long experience offered by NSTI is a first-level exposure to transportation engineering for many participants. We anticipate that NSTI participants who have had a spark of interest ignited in them about transportation engineering challenges will continue to develop their interest and explore challenges related to the transportation infrastructure.

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