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Outcomes and lessons learned from a First-time National Summer Transportation Institute Pre-college Program (Evaluation)

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Abstract

National Summer Transportation Institute (NSTI) is a pre-college summer program funded annually by the Federal Highway Administration (FHWA), hosted by universities, and managed by the Department of Transportation (DOT) of each state. The purpose of the NSTI program is to promote the interests of minority and underrepresented rising high school students in transportation related career and college degrees. In summer 2024, the Engineering Technology department at Middle Tennessee State University hosted our first ever NSTI program, which was 4-week long and non-residential. The program offered several field trips to various places and a curriculum consisted of three components: (i) Arduino programming and robotics challenges; (ii) computer vision and drones; (iii) traffic simulation using Simulation of Urban Mobility (SUMO). During the closing ceremony, the participants of the NSTI program presented what they had learned in front of the parents/guardians and the representatives from the civil rights division of our state's DOT. We conducted surveys among the participants before and after the program. The presentations and the survey results indicate that our NSTI program has greatly promoted the participants' interests in STEM and transportation related career.

This paper details the organization and execution of the NSTI program, including planning, participants recruiting, curriculum design, daily activities, field trips, presentations, and results of the robotic challenges. We also present the survey results and tips and lessons learned. We believe that this paper will be beneficial for the universities that wish to host the NSTI or any other similar pre-college summer programs.

1. Introduction

National Summer Transportation Institute (NSTI) is a pre-college summer program funded annually by the Federal Highway Administration (FHWA), hosted by universities, and managed by the Department of Transportation (DOT) of each state. The purpose of the NSTI program is to promote the interests of minority and underrepresented rising high school students in transportation related career and college degrees. See [1] for the history of the NSTI program. It has been shown in several studies that well-designed NSTI programs have a very positive impact to the participants [2]-[5]. In [6], Zhou et al. discussed the effectiveness of various educational instruments in their NSTI program. They found that building exercise and competition and fields trips are more of interest to the participants than some other activities such as software simulation and material testing. The NSTI program in [7] used hands-on activities involving Arduino in their curriculum and offered two training workshops to faculty members who taught the curriculum. [8] discussed strategies to foster students' interests in traditional research in transportation materials including plastic and SuperPave hot mix asphalt. Other success stories and lessons learned from various NSTI program in the past can be found in [9]-[14].

In our state, the NSTI program has been organized by a historically black university for more than 20 years, mostly in a residential format. In summer 2024, the Engineering Technology department at Middle Tennessee State University (MTSU) hosted our first ever NSTI program, which was 4-week long and non-residential. Our department has a B.S. of Engineering Technology program with three concentrations: Computer Engineering Technology, Mechanical Engineering Technology, and Electrical-Mechanical Engineering Technology. The department also has an engineering B.S. program in Mechatronics Engineering. This paper details the organization and execution of our NSTI program, including planning, participants recruiting, curriculum design, daily activities, field trips, presentations, and results of the robotic challenges. We also present the survey results and tips and lessons learned. Each NSTI program is unique in terms of the length and type of the program, curriculum, field trips, etc. We believe that this paper will be beneficial to the universities that wish to host the NSTI or any other similar pre-college summer programs.

The organization of the rest of the paper is as follows: Section 2 discusses planning and recruitment; Section 3 presents program schedule; Section 4 showcases the curriculum activities; Section 5 discusses the program evaluation and tips/lessons learned; finally, we conclude in Section 6.

2. Planning and Recruitment

The NSTI program at MTSU has a Program Director (PD) and a Program Assistant who are a faculty member and an academic coordinator in the Engineering Technology department, respectively. They worked together in Spring 2024 on the planning and recruitment for the NSTI program.

The following planning activities were done prior to the start of the NSTI program:

a) Formation of the Intermodal Advisory Committee (IAC). The PD has been doing research in Intelligent Transportation Systems for a long time, and he has established working relationship with many transportation professionals in the state. He invited staff members from the state DOT and the city’s transportation department to join the IAC. The IAC also consists of members from the civil rights department of the state DOT and local transportation consulting firms. The PD consulted the IAC members regarding the setup of the NSTI program as well as the possible field trips offered by the program.
b) Design of curriculum. Since the NSTI program has 4 weeks, three curriculum components were designed. The PD was responsible for designing the first component whereas the second and the third components were designed by a faculty member and a Ph.D. graduate student, respectively.
c) NSTI Personnel. In addition to the two faculty members and the Ph.D. student, two undergraduate Mechatronics Engineering students were selected and hired to facilitate the NSTI activities.
d) Preparation for STEM activities. We reserved a senior design lab for the program and set up 8 PCs/laptops with the needed software in that lab. Various parts and supplies were purchased prior to the start the program.
e) On-campus dining. The NSTI grant covered lunch during the 4-week period for the participants. The PD reached out to the campus dining ahead of time to coordinate the time and get the cost for the budget.
f) Coordination of field trips. The NSTI program offers several field trips during the 4-week period. The PD and the PA worked together to schedule the field trips with the hosts.

g) Arrangement of transportation. MTSU has a motor pool from which university personnel could rent vehicles for university businesses. The PD reserved vehicles from the motor pool and completed all related paperwork ahead of time for the field trips. The field trips needed two vehicles. The PD and a staff member in our department were the drivers.
h) On-campus activities. The PD contacted Campus Recreation and Student Union to get price quote and make facility reservations.
i) Participants paperwork. The PD obtained paperwork, including the agreement, acknowledgement of risk, release of liability and hold harmless, medical release, image consent, etc., for the admitted participants to sign.
j) Open and closing ceremonies. The PD and PA worked together to arrange for the open and closing ceremonies. Tasks included sending invitations to state DOT representatives, parents, and university administrators, reserving classrooms, providing parking passes to the event attendees, purchasing water and soft drinks, and preparing for prizes and certificates of participation.

The recruiting occurred concurrently with NSTI planning. The PD and PA worked with another staff member in the department to create a flyer, which contains the dates and highlights of the NSTI program, as well as the application link. The online application was designed by the PD using Qualtrics. The applicants were asked to provide their names, DOB, address, contact information, parents' information, school information, grade, GPA, standardized test scores (if any), an essay, transcripts, and two letters of recommendation. We asked the admission office of MTSU to send the flyer to local high schools and middle schools. Per state DOT's requirements, our program was targeted at rising high school students. About 50 applications were received although some of them were incomplete. After reviewing the applications carefully, the admission committee decided to accept 12 of them. The acceptance decisions were made based on the evaluations of the applications. Because most applicants were male, among the 12 participants, there were only two females, and the rest were male. 11 out of 12 students were minority and/or underrepresented students. Most of the participants were from local communities, but 3 of them were visiting the States from foreign countries.

3. Program Schedule

The 4-week NSTI program started on the Monday right after the Independence Day and run from July 8 to August 2. The open and closing ceremonies took place on these two days, respectively. Since our program was a non-residential program, the participants had to come to campus at 9AM and leave campus around 3PM Monday to Friday. In the morning, we usually ask the students to participate in STEM activities which will be described in details in the next section. In the afternoon, the students often go to field trips or conduct recreational activities on campus, which are shown in Table 1.

During the closing ceremony, the students were asked to make a team presentation in front of their parents/guardians. In the presentation, the students showed case their accomplishments and knowledge learned during the NSTI program.

Table 1. List of field trips and recreational activities

Location	Purposes/Activities
City's transportation department	To learn how traffic engineers manage and maintain traffic systems
Nissan plant	To learn how cars are manufactured
Nissan Training Center	To learn the technical programs offered by the training center
U.S. Space and Rocket Center	To learn aerospace transportation and engineering
Airport and the aerospace department	To learn more about airplanes and to try the flight simulator
University farm	To learn how to transport milk and produce
City's electricity utility company	To learn the role of electricity and electrical engineering in modern transportation
Experimental vehicles lab	To learn vehicle design and to ride the vehicles
Campus recreation center	Swimming, indoor soccer, pickleball, ping pong
Student union game room	Xbox/PS gaming, TV, air hockey, ping pong, pool
Maker space	Various fun and interactive activities

4. NSTI Curriculum

The NSTI curriculum has three components: (1) Arduino and robotics; (2) drones and computer vision; and (3) traffic simulation. The students spent the first 8 days to finish the first component. Then, they spent another 7 days to complete the second component. Finally, they focused on the third component in the last a few days. In what follows, we will describe each component in details.

4.1 Arduino and robotics

We used an off-the-shelf robotic kit: "OSOYOO V2.1 Smart IOT Robot Car Kit for Arduino" available at Amazon. It costs about $65 per kit and has a product page which contains 16 basic lessons (Fig. 1) and 8 sample projects (Fig. 2). The basic lessons are self-explanatory and have detailed instructions of circuit building and coding. Only a few participants had limited prior experience with Arduino and computer programming, but the kits are very suitable for beginners who do not have prior experience with Arduino programming and electric circuits. The NSTI participants were divided into 2-person groups, and all groups completed the basic lessons with ease. The sample projects are more complex but more fun. With the help of the two undergraduate daytime counselors, the participants finished those as well without issues. We organized two robotic competitions using the sample projects.

Robotic Competition #1: battle sumo

The robotic kit comes with an IR remote. In this robotic competition, the participants used the IR remote to control their robots, and the goal was to push other robots out of the ring shown in Fig. 3. Because the participants had limited knowledge in programming and computing, the challenge was mostly about how to modify the robots mechanically. The two undergraduate daytime counselors taught the participants how to cut metal using the metal cutting machines in the senior design lab. The NSTI participants then used their creativity to mount the metal pieces onto the robots they built before. See the modified battle bots in Fig. 4.

Basic Lesson 1: What is Arduino?	Basic Lesson 2: OSOYOO UNO Board
Basic Lesson 3: Download and Install Arduino IDE	Basic Lesson 4: What is a Sketch, and How does it work?
Library — Basic Lesson 5: How to Install Additional Arduino Libraries	Hello World — Basic Lesson 6: Hello World
Serial Monitor — Basic Lesson 7: The Serial Monitor	Basic Lesson 8: IR Remote Receiver Module and Controller
Basic Lesson 9: How to use IR to control the Active Buzzer?	Basic Lesson 10: IR Obstacle Avoidance Module
Basic Lesson 11: IR Track Sensor	Basic Lesson 12: Ultrasonic Sensor HC-SR04 Module
Basic Lesson 13: Controlling Servo Motor with IR Remote	Basic Lesson 14: Use the IR Control to Control a DC Motor Remotely
Basic Lesson 15: How to Use the HC-02 BLE	Basic Lesson 16: IR Transmitting Module and IR Receiving Module

Figure 1. The 16 basic lessons provided by the OSOYOO robotic kit

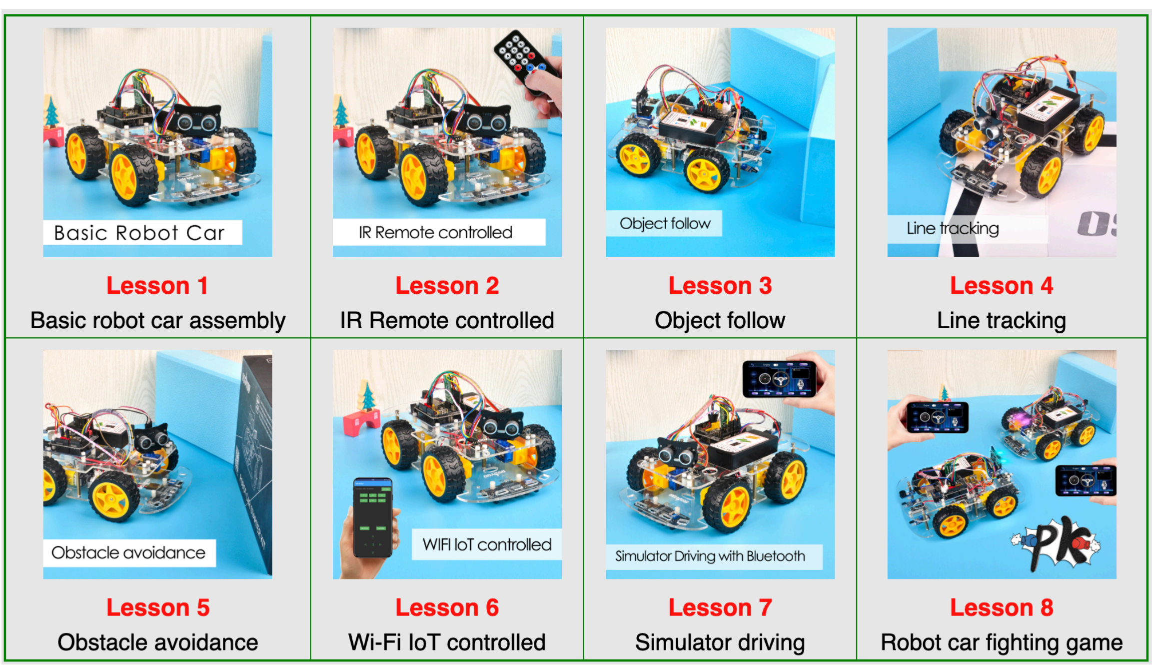

Figure 2: Tutorial and sample projects provided by the OSOYOO robotic kit

Fig. 3. Sumo battle setup

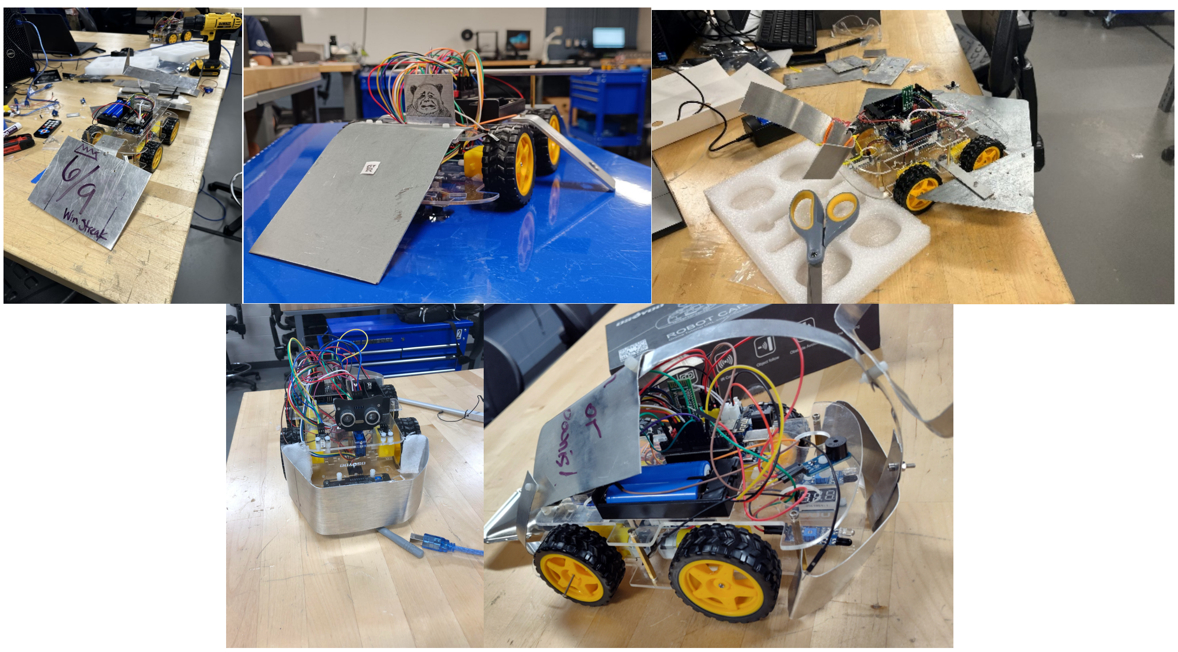

Fig. 4. Modified battle sumo bots

Robotic Competition #2: indoor soccer

Some of the participants are big fans of soccer, and we decided to do an indoor soccer competition. Fig. 5 shows the setup where each team has two robots, remotely controlled by the participants. The winning team modified the front end of the robot so that it could hold the ball with ease.

Fig. 5 Indoor soccer competition

4.2 Drones and computer vision

The curriculum of computer vision and drones has followed a systematic learning approach. In contrast to previous isolated learning of each subject separately, we integrated the learning of computer vision and drones together. It means that the learning of drones and computer vision were well integrated with hands-on activities, and therefore, it was easier for the youth to learn computer vision and its theory. The learning process started with having the youth be familiar with the subjects of computer vision and drones.

DJI Tello drones were used in the curriculum. Tutorials of drone were provided for the participants to have a solid understanding of drone control and navigation. The participants then used a drone simulator (Fig. 6) to become familiar with the flight of drones in different scenes, including both indoor and outdoor flying. Various level of difficulties in drone flying were also used to enable students experience realistic drone flying and immerse them with the hands-on activities brought forth through the process.

Figure 6. Drone simulator: learning how to navigate drones in different simulation environments

Next, the students were divided into several groups. Each group has two to three team members, and each team member was responsible for one of tasks. For example, if one team member is responsible for controlling drones, then another team member is responsible for learning how to use the drone camera and the third team member is responsible for learning how to process the photo using image processing and computer vision techniques. The responsibility of each team member was assigned based on the discussion with the participants to understand their background and interests. Some participants found it challenging to perform computer vision tasks using python initially. We overcame the challenges by carefully giving them tutorials of python about array, list, and dictionary operations as well as fundamental opencv knowledge. Tutorials on fundamental image processing techniques were also taught to the participants.

We had three activities of integrated learning of drones and computer vision. The first activity was the use of drones for face tracking. For this task, the participants were initially given examples of face tracking computer vision code designed for PCs. They were asked to become familiar with the example code and then improve the accuracy of the face tracking. Specifically, participants adjusted the Proportional-Integral-Derivative (PID) control gains to improve face tracking. Subsequently, the participants were asked to port the face tracking code to Tello drones to allow the drones to track faces (Fig. 7). The second activity was object recognition. In this task, the participants were asked to use the Yolo Computer vision framework to recognize objects, including human and vehicles, in different scenes (Fig. 8). Subsequently, the method was deployed to drones. The participants were also immersed in the research by flying drones outdoors to recognize cars and pedestrians. The third activity was to explore advanced vehicle speed estimate. The participants first downloaded some videos involving cars in motion and then were taught to process the videos with computer vision methods to estimate the speed of the vehicles in the scenes. The method was then deployed to DJI Tello drones. Subsequently, the participants estimated the speed of the vehicles on the street using the drones.

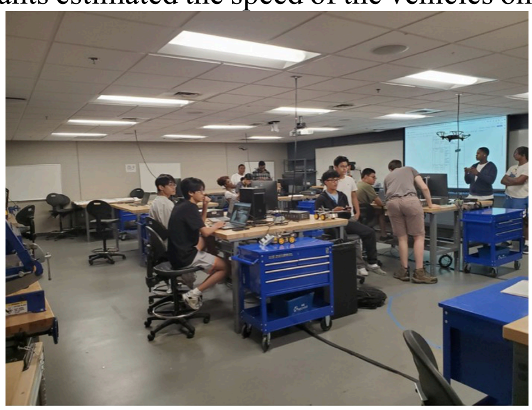

Figure 7. Drone face tracking in indoor environment

Figure 8. Face recognition using computer vision

4.3 Traffic Systems Simulation

The third part of our NSTI curriculum involved the development of vehicular traffic simulations using Simulation of Urban MObility (SUMO) software. Students were initially introduced to the software itself by generating simple, unidirectional roadway networks with SUMO's Netedit program. They then populated the road networks with vehicles and could run the simulations for as long as vehicles remained in the simulation. However, this meant that, unless a continuous vehicle flow was generated, after a set number of vehicles, most simulations quickly completed. Mitigating this rapid simulation completion due to a lack of vehicles being generated was easily resolved by educating students on how to modify their unidirectional roadway network to utilize a continuous circular roadway loop.

These SUMO basics were followed by two crucial assignments. The first of these assignments involved generating different types of vehicles and entities, such as passenger vehicles, trains, bikes, and pedestrians. Each vehicle type, or "vType," was assigned to its own lane to allow users to observe distinct travel patterns of each entity along the same roadway network. Students could then enhance their understanding of generating multiple vehicle types with the second crucial assignment involving generating multiple vehicle types that share the same roadway. An example of a roadway network designed by students for this activity is provided in Fig. 9. While the roadway network itself remained simple up to this point, the ability to create multiple vehicle types that share the same roadway allows for a more realistic representation of real-world traffic scenarios.

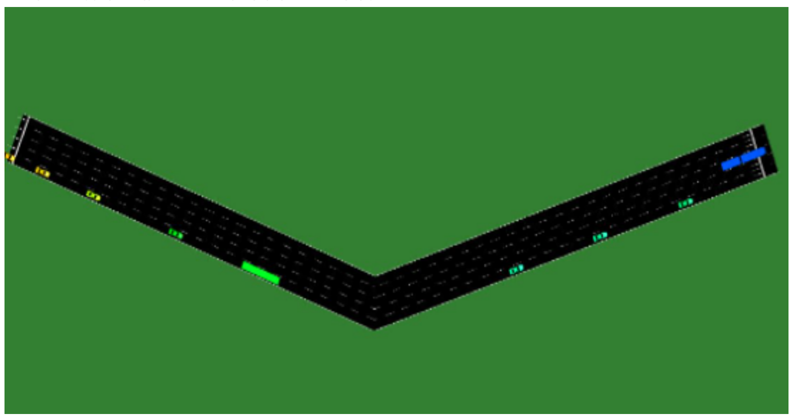

Figure 9. Roadway network of multiple vehicle types sharing lanes

Combining their knowledge of creating roadway networks and generating multiple vehicle types with continuous generation patterns allowed students to progress to the third major part of the traffic simulation portion of our workshop. The remaining four activities all utilized the students' previous experience and built upon each other to create more complex simulations. The first activity of this phase involved a simple four-way intersection involving sets of singular inbound and outbound lanes traveling in each direction and meeting at a central intersection. Students were only required to generate a single vehicle type during this phase to ensure they could adequately design their roadway network for the intersection, because they were also now required to learn how to design a traffic signal timing program which allows for more flexibility within the simulation. This activity was followed by a more complex version of the same intersection, though multiple new lanes were added, as were new vehicle types. When completed, students could execute a simulation of a four-way intersection with continuous vehicle generation of varying types, utilizing all the tools they previously acquired. The final two activities, which built upon the previous four-way intersection simulations, involved creation of a grid networks, because rather than simply simulating a single intersection, these activities aimed at using a grid setup with five intersections connected via various inbound and outbound roadways. An example intersection designed by students is provided in Fig. 10. These also involved adding additional lanes and vehicle types, all with the goal of creating more realistic simulations. This was the pinnacle of the students' SUMO simulations, because by completing these activities, they obtained all the necessary knowledge to create their own customized traffic simulations.

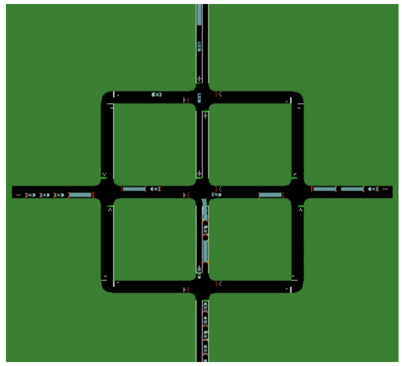

Figure 10. Grid network simulation from NSTI 2024

The culmination of all experience and knowledge related to traffic simulation resulted in a final project, where students were asked to develop their own roadway networks with their choice of design, including the number of different vehicle types and flows, to truly observe the depth of their understanding of the software. While some students relied upon more traditional network designs, others developed roadway networks outside of the norm to demonstrate both software comprehension and creativity.

5. Program Evaluation and Tips/Lessons Learned

The success of the NSTI program was well-demonstrated by the accomplishments of the students. They were able to build the robots, compete in the competitions, fly the drones, capture images and recognize people and cars, and run traffic simulation. All participants were very happy about the knowledge and skills they learned throughout the 4-week period, and it was evident during the final presentation when they presented the works to the parents/guardians. Some of them even demoed the flying of the drones in front of the audience. During the closing ceremony, the attendees including state DOT representatives, university administrators, and parents/guardians, were all very impressed with the students' presentations.

In addition to the above observations, we also performed surveys to evaluate the NSTI program. Before the NSTI program started, we asked the participants to answer 7 questions on the scale of 1 to 10, with 10 being the most familiar/confident/likely. 10 participants answered the questions, and the results are plotted in Fig. 11: most participants were not familiar with transportation and not confident with software programming, and half of the people were unlikely to pursue a transportation related degree or career. Fig. 12 plots the survey conducted after the NSTI program. The participants generally agreed that the NSTI program helped them learn more about transportation and related career, software programming, engineering, and teamwork skills. The post-NSTI survey also has fields for the participants to write the strengths and limitations of the NSTI program, and the results can be found in Table 2.

Based on the feedback from the participants, we have learned the following tips and lessons from the NSTI program:

Tip #1: Robotic competitions and hands-on activities can greatly promote the participants' interests. This is aligned with the findings in [6].
Tip #2: It is better to let the participants decide what robotic competitions they would like to do. In our NSTI program, we did not pick the robotics game; instead, we let the participants select the game to play. It turns out to be better since the participants are more motivated to work on the projects they are interested in.
Tip #3: Planning ahead is the key to success for NSTI.
Tip #4: Field trips could be very helpful in getting the participants engaged. In our program schedule, the STEM activities were mostly scheduled in the morning while most of the field trips took place in the afternoon. Such an arrangement helped the participants stay focused and made the summer program more fun. Several participants mentioned in the exit survey that they enjoyed the field trips and learned new things from them. This is aligned with the findings in [6].
Lessons #1: Recruitment needs to be improved. We initially planned to have 20 participants, but only 12 were accepted into the program. In the future, we need to find ways to encourage more qualified applicants, especially females, to apply. A residential program would be helpful in attracting students further away from the campus.
Lesson #2: On-campus transportation needs to be added. We thought it is okay to walk on campus, which is not very big, but the participants did not enjoy walking in hot weather. There was also an incident that one participant fell when running in the rain on the way back from the campus recreation center to the senior design lab. This could have been prevented if we had on-campus transportation.
Lesson #3: Need to have more guest speakers about transportation related career opportunities. Only half participants thought they are more likely to pursue a transportation related degree or career after taking NSTI. This motivates us to think that we would need to invite some guest speakers to further promote the interests of the students in transportation.
Lesson #4: Need to improve software testing when preparing for NSTI. After University IT department installed the needed drone software, we did not perform testing on all the PCs. As a result, some PCs had software issues that could have been prevented if more testing were done.

6. Conclusions

In this paper, we have discussed the implementation and evaluation of a National Summer Transportation Institute summer program which was hosted by Middle Tennessee State University for the first time. Details of how the program was set up and the schedule, curriculum, and outcomes of the program are presented. We consider the program a great success based on the final presentations made by the students as well as the surveys conducted in the end of the program. We have also identified a few tips and lessons learned from the program. They will help not only us improve the program in the future, but also other institutions who wish to establish NSTI or other similar pre-college summer programs.

Fig. 11 Pre-NSTI survey results

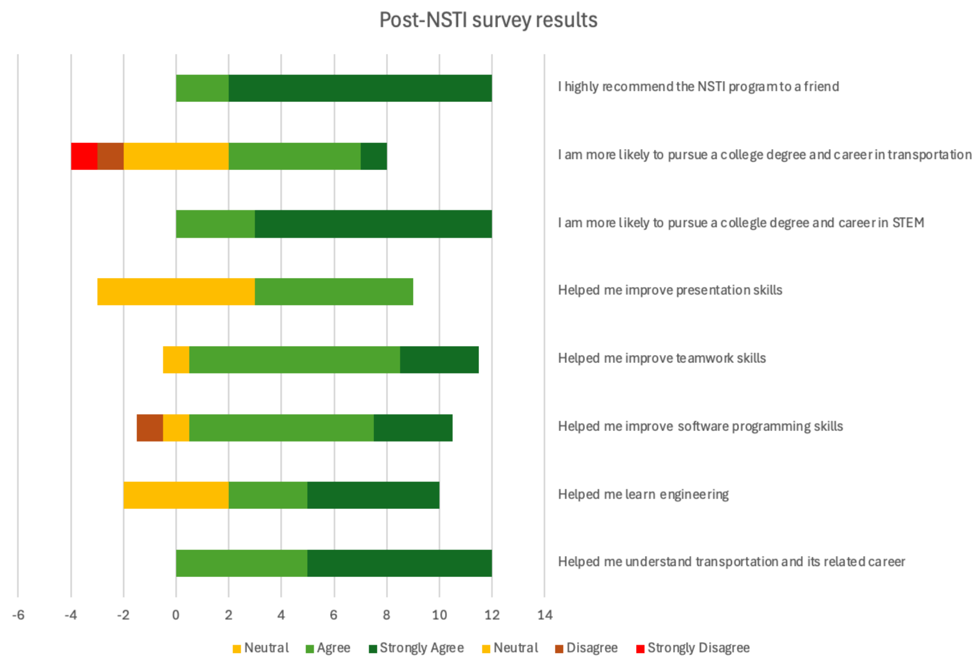

Fig. 12 Post-NSTI survey results

Table 2. Student survey: strengths and limitations of the NSTI program

Strengths	Limitations
Free lunch; Bonds between other students from other schools; Hands-on activities	Too much walk on campus
It's laid-back while you still learn stuff.	Not all the field trips gave free stuff.
Hands-on experience in building + learning new tasks; Have fun + build our bots to how we want to fight + make parts; Was able to learn new things I didn't know + can excel later on in life	Not anything but the transportation on campus. Great camp.
The teamwork; The activities that helped us learn about STEM; The trips.	Transportation around the campus.
They took us to many places that educated us on potential careers that I wouldn't otherwise think of. This program gives student so many opportunities.	The farm!
Free food; interesting field trips; lots of hands-on work; relevant and engaging projects	Projects drags on a little and can be confusing; the farm; the drone flying simulator (did not work half the time)
Fun works and trips	Too short
Field trips, hands-on	None
Being taught how to work with code, robots, and drones; being able to somewhat do what we want; being	None

allowed to go at our own pace; being given resources to work	
Able to learn a lot about transportation, engineering, and STEM	The program is too short.
Their way of teaching us which is very effective.	Personally, I have not seen any limitation. For me, the only limitation is time.
It allows you to make great discoveries in the scientific world which helps you to think bigger and increase your dreams in life and allows you to flourish.	I personally did not find any limit, only such an activity should have many more students.

IRB Statement

This study involved the collection of anonymous and non-sensitive survey data from high school students attending a summer camp. No personally identifiable information was collected, and participants were not exposed to any risk beyond those encountered in daily life. As such, this study was determined to be exempt from IRB review under MTSU's guidelines for research involving human subjects.

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