Introducing Transportation Engineering to Diverse K-8 School Students

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Abstract
Transportation engineering researchers at the Georgia Institute of Technology developed an active learning outreach program for Centennial Place Academy, a metro Atlanta public school that serves a racially and economically diverse student population with the majority of students falling into lower income brackets and minority populations. Georgia Tech researchers visited the school to conduct an initial session with the entire fifth grade class; this was followed by two full day sessions with a smaller subset of the same students after they had moved into the sixth grade. The program was designed to utilize cutting-edge technology to implement project-based STEM education with elementary and middle school students. The purpose of the program was to show students that engineering is an accessible discipline that utilizes many skillsets and encompasses multiple aspects of their lives. This paper describes final module designs that can be implemented in future engineering outreach initiatives.

Keywords
STEM Education, K-12, Transportation, Engineering

Introduction
As a part of an ongoing outreach effort, researchers at the Georgia Institute of Technology are leading hands-on activities related to current university research projects at Centennial Place Academy, a nearby public school. This initiative focused on introducing students to topics in transportation engineering and showing them that they could understand, conduct, analyze, and present on complex research topics in the field. The initiative was led by female engineers and was intended to encourage the diverse student body at Centennial Place Academy (49.8% Female, 86% African American, 5% Caucasian, 2% Asian, 3% Hispanic, 4% Multi Racial, 71% low income, as designated by federal standards) to consider engineering as an exciting and accessible field of study with many applications to everyday life.

The researchers were tasked with designing innovative approaches to engaging this young and diverse student population. Relatively few existing programs are intended for elementary school students. However, starting STEM education at a young age can give young students the confidence to continue studies in related fields. Transportation engineering provides a strong foundation for early STEM education because students are already familiar with transportation systems and have been exposed to transportation problems in their everyday lives. Therefore, researchers focused on aspects of the field that are tangible to students. In addition, researchers dedicated themselves to applying modern technologies (e.g. smartphones and tablets) and new software applications to the learning process. The research team introduced the students to innovative transportation related smartphone and tablet applications developed at Georgia Tech that are currently being used for data collection, data analysis, quality analysis, and public outreach in on-going research projects. These technologies proved to provide an effective platform for sustained student engagement.

The outreach initiative was held in two sessions: an initial overview and introduction for the entire class and a second, in-depth two-day research session for a small group of interested students. The first session, held in May 2014, introduced over 80 fifth graders to elements of engineering such as measurements, data analysis, presentation, and teamwork. It focused on interactive transportation activities covering accessibility challenges using wheelchairs, mode choice mapping and modeling, and paper and electronic travel diary activities. The follow-up sessions, held in October 2014, involved 17 sixth graders who chose to participate. These sixth graders worked directly with Georgia Tech researchers to conduct and analyze data and present their findings for three different modules: 1) accessibility design; 2) human factors and the roadway environment; and 3) traffic operations. The modules that were designed for each session, as well as leadership guidelines and materials needed for each module are transferable to other schools and student populations. This includes various ages and educational levels as indicated by the considerable overlap in activities undertaken by the middle school students with activities from previous outreach efforts at public high schools and undergraduate research initiatives. The developed modules and methodology are outlined in this paper with the intention of providing resources for similar outreach initiatives.

The research team recruited volunteers to help lead the initiative from Georgia Tech student groups with a commitment to service, such as the Institute of Transportation Engineers (ITE), and Women's Transportation Seminar (WTS). The initiative was conducted by high school, undergraduate, graduate, and post-doctoral researchers, leading to opportunities for researchers at all levels to take on both mentor and mentee roles throughout the program.

Background

As a nation, U.S. students lag behind on international assessments for mathematics and science. For example, only 10% of U.S. eighth graders met the international benchmark in science set forth in the Trends in International Mathematics and Science Study, compared with 32% in Singapore and 25% in China.[1] As measured by the National Assessment of Educational Progress, approximately 75% of U.S. eighth graders are not proficient in mathematics by the time they complete the eighth grade. Furthermore, significant achievement gaps exist between white, high-income student populations and underserved student populations, which include women and minorities. These gaps indicate that the average student in the underserved groups of minorities and low-income students perform around the 20th percentile rather than the 50th percentile.[2] Research shows that biases in gender, race, and other socio-economic traits from a young age play into students' choices in what to study, what their terminal degree will be, and what career they will enter.[3] For example, a study done at the University of California, Los Angeles found that Black, Latino, and Native American students who initially began college as STEM majors had four-year STEM degree completion rates of less than 16%.[4] These statistics not only indicate the need to improve the performance of U.S. students in mathematics and science in relation to the rest of the world, but also the increasing need for a qualified, motivated, and diverse STEM workforce. Together, these needs have led to a national focus on STEM initiatives in K-12 education across diverse student populations.[5]

Historically, engineering has not been a K-12 subject. Nationwide, STEM education initiatives in elementary, middle, and high schools are becoming more prevalent, however, very few K-12 teachers engage in engineering education and expose their students to engineering concepts and activities.[6] Several studies have indicated that inadequate preparation at the elementary through high school levels is the leading obstacle in increasing involvement of members and under-represented populations in STEM fields. In a survey conducted by Bayer Corporation, [7] more than 77% of the female and underrepresented minority chemists and chemical engineers polled stated that significant numbers of women and underrepresented minorities are missing from the U.S. STEM workforce today because they were not identified, encouraged, or nurtured to pursue STEM studies at an early stage. From the chemists polled, interest in science actually began at an early age, regardless of gender, race, or ethnicity: 59% said they first became interested before the age of 11. Across the board, those polled stated that their school science classes were the most important factor in stimulating their interest in science. Also, with respect to individuals who were most important in sustaining their interest in science at both elementary and high school levels, science teachers were cited as being most important by all of the chemists and chemical engineers polled. Such findings are echoed by Bonous-Hammarth,[8] who adds that experiences in undergraduate and graduate education that will lead to interest and success in STEM jobs are shaped by preparation in grade school. Common factors found in research about including all genders in the learning environment include using active participation, projects, emphasis on collaboration and communication, and using real life examples can help engage all students in the material regardless of gender.[9]

It is clear from the findings of the studies above that early exposure is vital in encouraging women and minority groups, as well as the general student population, to pursue STEM fields. As pointed out by Katehi et al., [10] the integration of engineering into K-12 education has numerous potential benefits, some of which are listed below:

- Improve nationwide learning and achievement in STEM
- Increase student's awareness of engineering and the work of engineers
- Develop students' understanding of and ability to engage in engineering design
- Spark interest in pursuing engineering as a career
- Increase technological literacy in a very technology-dominant economy

Similarly, the National Research Council also believes that early exposure to STEM supports children's overall academic growth, develops early critical thinking and reasoning skills, and enhances later interest in STEM career paths.[11] These studies clearly demonstrate the potential of K-12 engineering education in reversing the declining numbers of the U.S. STEM workforce while addressing issues of underrepresentation of women and minorities in engineering.

Goals and Objectives

In developing the modules and program for this initiative, the research team had the following general objectives:

- Show students that engineering is an accessible discipline encompassing many aspects of everyday life and different skill sets including mathematics, presentation, communication, critical thinking, organization and planning, and the ability to work in teams
- Cultivate social responsibility among students by showing them that engineering can increase safety for all transportation system users and improve quality of life for all including people with limited access and mobility
- Encourage young women and minorities to consider engineering as they continue learning
- Give students an overview of transportation engineering through projects and technologies

- Showcase real-world applications of engineering through project-based learning
- Provide mentorship and volunteer opportunities for undergraduate and graduate level students, specifically reaching out to the Institute of Transportation Engineers (ITE) and Women's Transportation Seminar (WTS) at Georgia Tech

These general objectives of the initiative align well with the national K-12 education in STEM goals of the U.S. Department of Education (DOE) set for the Committee on Science, Technology, Engineering, and Math Education (CoSTEM) that was developed in 2010. The DOE asserted that CoSTEM was created to serve as a national committee to work towards goals in STEM education and career development by coordinating federal programs and developing a strategic plan that improves: 1) the impact of funding towards P-12 (preschool to 12th grade) STEM education programs, 2) youth and undergraduate student involvement with STEM subjects, 3) service to historically underrepresented populations in STEM fields, and 4) graduate education towards the STEM workforce.[12] CoSTEM's 2013 Strategic Plan speaks towards these goals, specifically noting objectives set by the administration, such as President Obama's call to action to Federal scientists and engineers to "volunteer in their local communities and think of creative ways to engage students in STEM subjects."[13] Outreach initiatives such as the one described in this paper provide these opportunities for community engagement. The program also directly relates to President Obama's goal to prepare 100,000 excellent STEM teachers over the next decade by training high school, undergraduate, and graduate students in engineering with teaching and mentorship skills, and by engaging middle school students in engineering topics and methodologies to spark potential interest in pursuing engineering studies.[14]

The general project objectives also align with those of Centenial Place Academy as it begins its first year as a charter school. Strengthening ties between the Georgia Institute of Technology and Centennial Place Academy communities, as well as introducing students to research topics and methods, works towards Centennial Place's core "educational goal that all students schooling in the new community go to and graduate from the Georgia Institute of Technology or other comparable institutions" as well as Centennial Place Academy's overall goals to "prepare students who are ready for rigorous, college preparatory high school instruction" and to "engage a strong community focused around educating our children."[15]

The research team also developed a more focused set of research method objectives for the initiative. At the end of the sessions it was intended that the students be able to:

- Identify and explain multiple topics in transportation engineering
- Ask current questions related to transportation engineering topics
- Collect data with both manual and technology-driven instruments
- Analyze data using basic statistical functions and reasoning
- Articulate through a problem statement, hypothesis, data collection and analysis methods, and conclusions for their completed module
- Design and give a presentation that effectively communicates with the audience

Methodology

Researchers visited the school to conduct the sessions. Members of the lead research team planned out each visit ahead of time with lesson plan outlines and an assessment of the necessary equipment, materials, and leadership personnel. During the breakouts by module, one member of the main research team went with each group to help keep the sessions aligned with the lesson plans, goals, and objectives.

The first session provided an overview for the entire fifth grade (82 students) in May 2014. Fifteen Georgia Tech researchers participated in leading full class opening and closing presentation/discussion and three subgroup activities on 1) accessibility; 2) travel mode choice; and 3) travel diaries.

The second session was held on two consecutive days in October 2014 with only 17 students from the original group of students who elected to participate. This smaller group of students was well distributed between males and females, and most of the students were African American, mirroring the demographics of the Academy as a whole. The students were divided into three groups designed to expose them to three transportation engineering modules: 1) Pedestrian Accessibility; 2) Visual Complexity and the Roadway Environment; and 3) Traffic Engineering. On the first day, students rotated through each module and conducted both manual and automated data collection techniques. Manual data collection included activities such as performing vehicle counts on paper, measuring width and slopes of pedestrian paths, and rating images of roadway conditions, while automated data collection techniques involved tablet computer technologies. On the second day, the three groups were assigned to one of the three modules for the entire day where they analyzed the data collected from the previous day and prepared a presentation on their respective module for their peers and research mentors.

Activity and Resource Development

The research team developed transferable material in terms of the activities and associated resources and equipment for each of the modules. They included presentation slides to accompany introductions to both sessions, worksheets for the accessibility module in both sessions, large printed maps of the school district with easy to read marked neighborhood centroids and school buildings, a collection of images for assessing roadway visual complexity, traffic count sheets and videos for traffic engineering, and a template for final presentations. These materials are available for free through the Georgia Institute of Technology website.

Assessment Techniques

At the end of the first day of the first session, the research team held a full group discussion with the students, which allowed the research team to understand how familiar the students had become in transportation engineering topics. Additionally, written activities such as completing checklists, filling out travel diaries, and mapping travel routes in each module helped to assess how the students were following along as they participated. Their comments and questions about the activities in which they partook, as well as many questions expanding beyond the scope of the designed activities, demonstrated that students had followed and understood the presentation and activities and were thinking critically about the topics. The high mentor-to-student ratio for the second session allowed for formative assessment through discussions with the students as to the best methodologies and meanings behind the results obtained from the data collection and analysis activities. Ultimately, the final student presentations served as a cumulative assessment of how much the students were able to accomplish and what parts of the research process they were able to articulate to the rest of the group. Complete presentations with problems statements, clearly identified hypotheses, data collection techniques, data visualization and analysis, and conclusions suggest that the students were able to complete the objectives of the projects and benefited from the time spent on the activities. Every student spoke in the presentations and many students asked questions of their classmates to further their knowledge showing interest in the research topics.

Description of Modules

Session 1

The first session took place in May 2014 with the entire fifth grade class of 82 students and lasted approximately two and a half hours (9am-11:30am). The session began with an interactive PowerPoint® overview of the field of transportation engineering in which the students contributed what they knew about transportation and asked questions. The research volunteers then divided the class into three groups, each focusing on one of the following three topics.

Accessibility. The goal of the accessibility topic was to introduce the students to the importance of providing easy access for all users of the transportation network, particularly the disabled population. To meet this goal, the accessibility group asked one student in the group to use a non-motorized wheelchair and they were asked to complete a series of everyday tasks at different locations around the school together with the rest of the group. The students were able to observe and take note of real-world examples of some of the ease and/or difficulties that the disabled population is exposed to on a daily basis.

Mode Choice. The mode choice group had students estimate their home location (aggregated by neighborhood for privacy purposes), and state their primary mode of transportation between home and school. Research volunteers developed mode choice models for home to school trips using distance as an independent variable. The students interpreted the graphed models and made predications about what would happen if more students moved closer to school or if we developed “super shoes” to allow people to walk twice as fast.

Travel Diary. The travel diary group filled out individual travel diaries by remembering trips they took in the last few days. They used the same original paper survey instrument that was used in the widely distributed Georgia Tech Commute Atlanta study in 2004.[16] Students also looked at smart phone electronic travel diary data collected with second by second GPS tracking and discussed the advantages and disadvantages of paper versus electronic travel diaries. Figure 1 on the following page shows screen shots of the smart phone data collection app, Commute Warrior, a smartphone application developed by the researchers at Georgia Tech.[17] Exposure to the Commute Warrior App gave students insight into the role of programming and technology in improving data collection and usability methods through current projects underway on Georgia Tech’s campus as related to transportation engineering and human behavior studies.

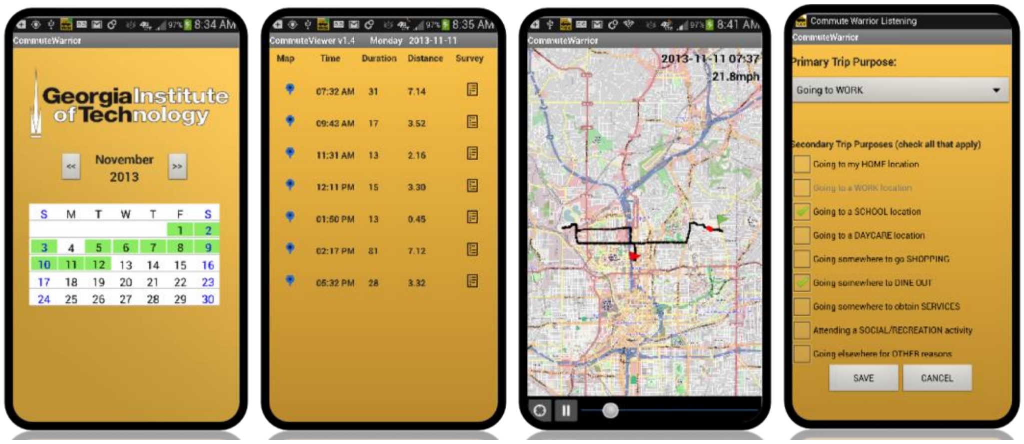

Figure 1. Commute Warrior Electronic Travel Diary and Mapping Screen Shots

Students were intrigued by the automatic data collection enabled by the smart phone app, and were excited to learn how technologies have changed the way people conduct transportation research. To conclude the first session, all of the groups came together and discussed what they did, what they learned, and additional questions that they had regarding the exercises.

Session 2

The second session was held over two days in October 2014 (8am to 3pm) and involved 17 students from the original group who had elected to participate in the program. The session began with an overview presentation and discussion aimed at reviewing the topics covered in Session 1. Afterwards, the students divided into three groups and experienced three different modules of transportation engineering: 1) Pedestrian Accessibility, 2) Visual Complexity and the Roadway Environment, and 3) Traffic Engineering. On the first day, the three groups rotated through each module and conducted both manual and automated data collection techniques associated with each topic, exposing the students to each of the three topics. On the second day, each of three groups were assigned to just one module and they analyzed the data collected from the previous day and prepared a presentation that they presented at the end of the session.

At the end of the first day, the three groups of students came together to reflect on and discuss the modules. The students wrote their most and least favorite aspects of each module on a sheet of paper and shared them with the group. This allowed for the students to recall the objectives of the modules that they had previously completed, and actively engage in the material by summarizing their feedback in written form and sharing them with their fellow classmates. This step was used for the students to reinforce the knowledge and skills learned in the previous day, and for the researchers to quickly assess student attitudes and make necessary adjustments.

To start the second day, Georgia Tech researchers led a lesson on basic statistical tools used in data analysis in order to facilitate the agenda for the rest of the day. The statistical overview consisted of an interactive discussion incorporating whiteboard illustrations and data sets collected on the spot such as travel time to school and favorite ice cream flavors. Examples and definitions of concepts such as means, medians, and charts, some of which were new to the students and some of which were a review, helped to prepare the students to analyze their own data later in the afternoon. The skills presented are consistent with Common Core standards for the sixth grade.[18]

Each module including the data collection and analysis methods are described in detail below.

Pedestrian Accessibility. The objectives of this module were for the students to 1) experience how people with limited mobility use pedestrian facilities; 2) learn how to use tape measurers, smart levels, and tablet technologies to collect data; and 3) analyze and present the collected data. This module brought students to three different locations in their school environment to measure aspects of pedestrian accessibility. Students collected data to fill out a worksheet on width, cross-slope, vibration, and additional amenities in the main school hallway, the sidewalk path leading to their playground, and a wooden slatted bridge connecting the elementary school facilities to the new middle school facilities. Students developed hypotheses as to which pathways would feel more or less accessible in general; which would be smoother, have more or less of a cross-slope; and which would be narrower or wider.

On the first day of the session, students worked in groups of two to manually collect data for all three locations. They collected width data using tape measurers, cross-slope data using digital read out smart levels, and roughness data based on their subjective opinion on how the surface felt when traversed in a standard wheel chair. Each student was required to experience all three corridors using a standard issue manual wheelchair, maintaining control of the chair on all surfaces, including inclines and slippery surfaces.

On the second day of the session, students used Sidewalk Sentry[19], an automated sidewalk data collection software for tablets developed by Georgia Tech researchers that harnesses the accelerometer and gyroscope in the tablet, to collect vibration data and uses a semi-automated video processing technique for width estimation. The tablet is mounted onto the same standard wheel chair that the students used to manually collect vibration data and measures changes in the x, y, and z directions. Students entered the manual and automated data into Excel® and performed statistical analyses to estimate average and minimum width for the three different pathways, average and maximum cross-slopes, and compare both manual and automated vibration data. Figure 2 below shows the students presenting their data from the tablet accelerometer data collection organized in a separate graph for each location.

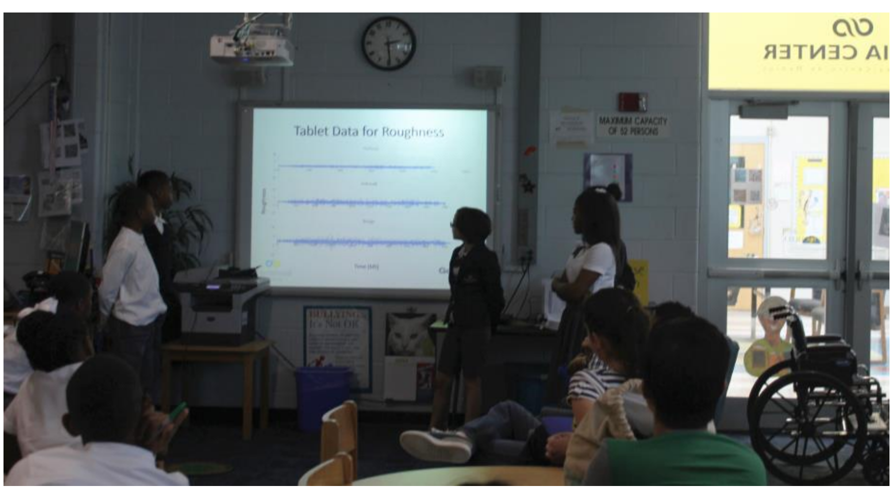

Figure 2. Student Accessibility Presentation

Afterwards, the students reflected on their results and built a presentation covering the research questions, their hypotheses, data collection methods, results, and conclusions. Some of the results surprised the students, such as that the hallway is not completely flat and that the sidewalk did not feel very smooth.

Visual Complexity and the Roadway Environment. This module was intended to introduce students to the research process associated with the design of safer transportation systems for all users. The researchers began the breakout session by leading a roundtable discussion with the students about what they believe are the greatest risks and distractions in the roadway environment. This allowed the students to share their own personal experiences and stories about roadway environments, enabling them to relate to safety issues in roadway environments. The discussion was then steered towards a deeper examination of elements in the roadside environment that they believe contribute to driver distraction and confusion.

After the opening roundtable discussion, the researchers presented several photographs of real world roadway environments from California and Georgia under different environmental conditions. The students were asked to rate each photo on a scale of 1 to 5, with 1 as least complex and 5 as most complex. A sample image can be seen on the screen in Figure 3 below.

Figure 3. Roadway Environments

Each student rated the images by placing a sticker in the 1,2,3,4 or 5 columns of a bar chart that was drawn on the board. After each image, the students were asked to explain their ratings, and the researchers illustrated that based on personal experiences and varying perspectives, everyone has a different but equally justifiable analysis of the complexity of the roadway environment. Additionally, there were common elements that emerged for every image as being potentially dangerous for drivers. These elements were further explored and the students were asked to make common factor groups of the elements. From this activity, factors such as traffic, people, billboards, and workzones emerged as common themes.

Following this activity, the students were asked to brainstorm about experiments that could be used to test driver perception of roadway environments. During this process students were exposed to the concept of using a driving simulator to safely study driver perception in a controlled environment. Some of the images used in the experiment were simulator images, and one of the purposes of this was to see if people rated the simulator images lower than real world images. The students were shown images and videos from the National Advanced Driving Simulator (NADS) MiniSim that is used by Georgia Institute of Technology researchers to study driver perception.

After this, the researchers asked the students to verbalize the research problem, identify the dependent and independent variables being studied, and finally to make hypotheses about what they thought the data would show. The actual experiment designed by the research team at the Georgia Institute of Technology was then presented and explained to the students. This experiment is implemented using a human factors software platform called Inquisit by Millisecond Software. The researchers explained all facets of the experimental design associated with this experiment, and then the students were able to take the experiment themselves. This was an exciting activity for the students, and they were eager to share the flaws of our experimental design as they participated in the experiment. Some students suggested redesigning certain portions to give respondents more time to view the images. Their suggestions were problems that the research team had grappled with in the initial experiment design.

Following the experimental design step, the group examined the data outputs, and talked about methods of analyzing the data with descriptive statistics and graphs in an interactive activity using the whiteboard. Students suggested organizing and comparing the ratings by individual students, by images rated, and finally by simulator or real world environment images. Next, the group of sixth graders was invited to form a circle on the ground, and a researcher projected a Microsoft Excel® worksheet with the data on the screen. The students helped the researcher to design an Excel® spreadsheet that could be used to analyze and present the data. Finally, students were shown many simulator videos that the researchers had built to test varying classes of factors. The students identified the factors being studied for each video, and then engaged in a discussion regarding the realism of the simulator scenes.

On the second day of the module, students participated in data entry of the ratings that they had collected while testing the Inquisit experiment on the previous day. The researchers walked them through setting up an Excel® worksheet and then showed them to take averages and medians using both manual methods and the built in formulas in Excel®. Once the data were entered and the measures of descriptive statistics calculated, the students learned how to make histograms to compare ratings between the simulator and real world environments. The students then participated in group discussions, and drew conclusions based on the summarized data as a team. The students discussed their hypotheses, and reflected on who had made correct predictions during the previous day. Following this, the students made a research presentation together detailing their research problem, variables examined, hypotheses, experimental design, and data analysis. They also made individual research brochures to take home that contained a summary of the research process they had just applied.

Traffic Engineering. The objectives of this module were 1) to introduce the field of traffic engineering and its significance in daily life, 2) to introduce common vehicle count data collection techniques, and 3) to discuss and demonstrate their application and significance in traffic engineering through hands-on activities using tablets and computer-based traffic simulation. On the first day, the researchers began by giving an interactive presentation aimed at introducing the students to the field of traffic engineering and its significance in their daily lives. As part of the exercise, they were asked to share what they thought of the following questions:

- What is the traffic system made up of?
- What does it mean to engineer traffic? Why is it done?
- What does it take to engineer traffic? What types of data are needed?
- How is performance measured? How does one know if the system is performing well or poorly?

This exercise allowed the students to share their own experiences and perceptions about the traffic system. Their input allowed them to realize that they already had a good knowledge base about traffic engineering and how it plays an important role in their daily lives. The researchers then dove deeper into the data and methods used in traffic engineering, in particular the importance of vehicle volume data and how these data are collected. The students were briefly introduced to the different methods of vehicle volume data collection techniques including manual vehicle counting, electronic count boards, tube counters, and video and tablet counting.

The module allowed the students to have first-hand experience in collecting vehicle volume data while reaching towards the overarching goal of allowing the students to apply the scientific method to traffic engineering. To achieve this goal, the students were first given a problem that they were asked to evaluate and come to a recommendation. They were asked to be traffic engineers for the day and to collect vehicle count data for one particular intersection: Heards Ferry Road and Riverside Drive in Sandy Springs, Georgia. This was an actual intersection that the researchers had video data on at Georgia Tech. The students were asked to watch a 15-minute long video of the intersection and to collect vehicle volume data in two ways: 1) by the manual counting method and 2) the video-and-tablet counting method as seen in Figure 4 below.

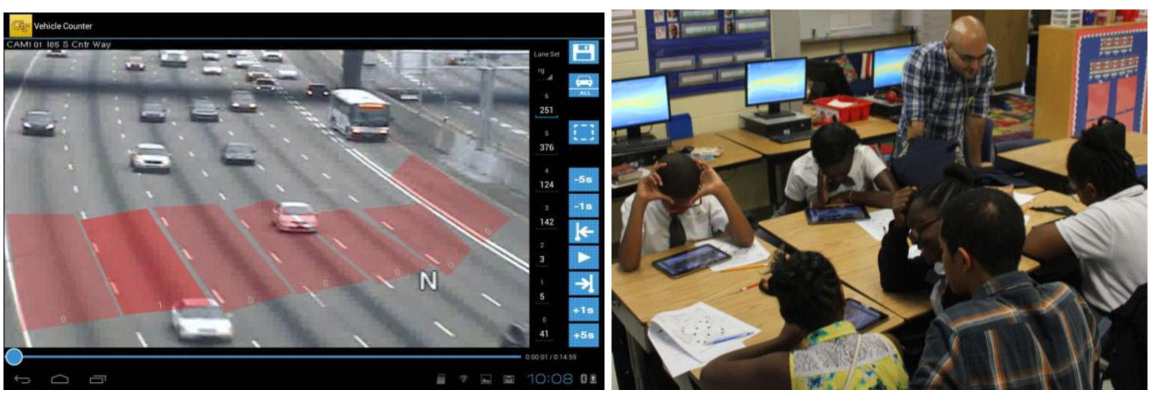

Figure 4. Georgia Tech Application for Vehicle Counting on Smart Tablets in Use by Centennial Academy Students

Once the data were collected, the students were then asked to compare the results of both method and to recommend the best data collection technique. Prior to beginning with the data collection activities, an open discussion was conducted by the researchers to help form the students' expectations of the two methods and thus generate hypotheses for their activity. The researchers asked the students the following questions:

- Which method do you think will be more accurate and/or efficient?
- What do you think are the advantages and disadvantages of each method?
- Do you think the two methods will yield the same results? Why or why not?

Once they answered the above questions and formed their hypotheses and expectations for the activity, the students began with their hands-on activities. First, the researchers helped them to perform manual vehicle counting using a video of the intersection, a data collection sheet, and a pencil/pen. After a quick demonstration, the students were asked to tally the vehicles they see in the 15-minute video as they travelled through the intersection, ensuring that they noted which direction they were coming from and going to. After the manual counting activity, the students were asked to perform the video-and-tablet vehicle counting activity. In this activity, each student was given a tablet, which contains the same video of the same intersection that was shown previously. They watched the video through a Georgia Tech-developed tablet application. The tablet application allows users to define zones on the video on which they can then tap as vehicles move across them, and the tablet application will automatically record the number of taps on each zone. After a quick demonstration, the students were again asked to perform the activity for a span of 15 minutes. Once both of these activities were completed, the students were asked the same questions that were asked at the beginning of the activities, allowing them to reflect on their hypotheses and initial expectations and compare to their experience with the two methods. This completed the first day of the session.

On the second day, the students were exposed to data analysis techniques and presentation preparation in PowerPoint®. Georgia Tech researches aggregated the manual and tablet count data collected by the students on the first day in an Excel® spreadsheet that was then distributed back to the students who were asked to analyze the results of both counting methods through computing several descriptive statistics. Students also compared the results in multiple bar and column graphs, and used the visuals generated to recommend the best data collection method.

The second day exposed the students to data analysis. Researchers aggregated the manual and tablet count data collected by the students on the first day in Microsoft Excel®. This Excel® file was distributed back to the students, and they were asked to compute several descriptive statistics based on the data and to generate graphs and/or charts to visually show their findings with one-on-one assistance from circulating researchers. Georgia Tech researchers and volunteers were present throughout the entire session to help them in conducting the different analysis techniques and in generating the visual results in Excel®. Once they completed their analyses, the students worked together to create their group research presentation and to make individual research brochures to take home to show to their parents.

Student Presentations. At the end of the second day, each small group of sixth grade students delivered a presentation on their break-out research project to the rest of the group using PowerPoint® slides and actual data collection equipment as visual aids. The students demonstrated an understanding of the research process, showed confidence and enthusiasm about the research topics, and clearly communicated the methodologies, analyses, and applications of the data they collected. Figure 5 on the following page shows one of the student groups presenting on their data analysis of roadway visual complexity ratings.

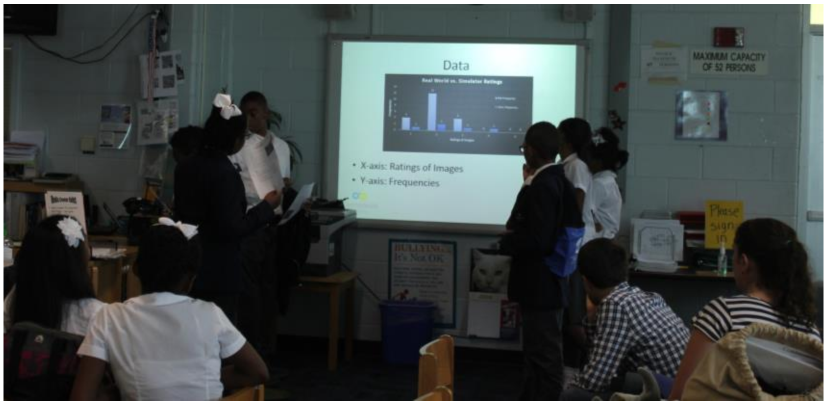

Figure 5. Student Presentation on Roadway Visual Complexity Ratings

Conclusions

This initiative is unique in the use of cutting-edge technology to engage elementary/middle school students in project-based STEM education. The application of mobile technologies, especially the newest applications developed in on-going research efforts, not only excited students, but also led them to re-think the learning opportunities around them. Students learned how researchers can harness features built into existing technologies to measure variables such as speed, vibration, and geographic location, and were able to compare the data collection methods to manual methods that are still more widely used today despite the available technologies. The project-based approach, grounded in ongoing research, integrated science, technology, engineering, and math, aligning with the STEM definition by Georgia Department of Education.[20] The rotation of students across projects exposed students to multiple aspects of the transportation discipline. In the meantime, students were able to go through the entire scientific inquiry process within a project, allowing them to have a thorough understanding of the evolving nature of research.

The final student presentations demonstrated that the initiative was effective in teaching concepts, skills, and ethics.

- Concepts – Students grasped basic concepts in transportation engineering and statistics. They demonstrated understanding of transportation engineering concepts, such as roadway design, operations, and accessibility, through their problem definitions and research implications. They also showed understanding of statistical concepts, such as average, range, and variability, through data analysis and interactive question and answer sessions.
- Skills – Students gained important skills ranging from data collection, data analysis, data visualization, and oral presentation. Students experimented with a variety of ways to collect, analyze, and present their data. They also gained experience working with software packages such as Excel® and PowerPoint®.
- Ethics – Engineering ethics was embodied throughout the modules. The mode choice module in session 1 showed students the need to consider diverse modal needs of travelers in the transportation planning process. Students experienced first-hand in the wheelchair module the huge differences engineering design can make in the daily activities of a person with disabilities. In the traffic operations module, students learned about the varying quality of primary data, and the consequences of sub-quality data. The roadway complexity module showed students how roadway design potentially affects traffic safety. All of these elements reinforced the sense of responsible engineering practice among the students.

The active learning techniques and modules developed for this programming are transferable and may be expanded upon for further use in the same or different curricula. Data collection techniques practiced with the students are ones employed by the research team with high school, undergraduate, and graduate researchers as well, demonstrating the longitudinal relevancy of the program. Showing young students who are member of demographic groups that are under-represented in engineering that they have the skills and resources to pursue engineering will lead to higher levels of interest in the field among diverse populations.

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