MARITIME TRANSPORTATION RESEARCH AND EDUCATION CENTER
TIER 1 UNIVERSITY TRANSPORTATION CENTER
U.S. DEPARTMENT OF TRANSPORTATION

MarTREC
Maritime Transportation Research & Education Center

Interdisciplinary Education Outreach with Traffic Sensor Build Kits

August 2019 – May 2020

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July 2020

FINAL RESEARCH REPORT
Prepared for:
Maritime Transportation Research and Education Center

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ACKNOWLEDGEMENT

This material is based upon work supported by the U.S. Department of Transportation under Grant Award Number [69A3551747130]. The work was conducted through the Maritime Transportation Research and Education Center at the University of Arkansas.

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1 Project Description

1.1 Project Overview and Objectives

The goal of this project was to attract K-12 students to transportation engineering careers through STEM outreach programs. To accomplish this goal, the object of the project was to design and implement maritime freight oriented educational outreach activities centered on traffic sensing technologies for middle, high school, and first-year college students. In MarTREC Project 5011 (Evaluating the Performance of Intermodal Connectors), the research team designed a low-cost, easily implementable LiDAR and Bluetooth sensor bundle that was capable of detecting, characterizing, and tracking freight trucks as they traveled to and from inland waterway port areas. The sensor provided data necessary to measure port performance and roadway usage by industry. This project re-designed the sensor bundle as an educational outreach activity by creating sensor "build kits" and associated lesson plans for middle school, high school, and first year university students. The concept of the build kits as a tool was highly praised when presented by the PI to professionals at the Missouri Valley Institute of Transportation Engineers (MOVITE) fall meeting in 2017.

"Build Kits" is how we describe a concept borrowed from the Boy Scouts' Pinewood Derby Car Kit, in which everything needed for a successful program comes pre-packaged and ready to use. These build kits were intentionally designed to be scalable and interdisciplinary programs that introduce maritime topics to students ranging from middle school up to college freshman engineering students. The outreach program is scalable in the sense that various parts of it can be included or excluded/re-invented given parameters such as program length or access to technology. This ensures that the program is an appropriate length and the content is appropriate for the setting or age group of participants. This interdisciplinary program includes concepts and tools from transportation engineering, computer science, coding, and data analytics through a variety of hands-on opportunities.

The Build Kit contains components to build a mini-inductive loop detector from off-the-shelf, low-cost components. The mini-inductive loop (12 in. or less in diameter) connects to a detector card that translates the inductive signal from the loop to an open-source software. The software is used to change loop settings like sensitivity, and to view and download loop readings. The inductive loop can measure the metallic components of a vehicle and is used to classify trucks and cars which have different metal chassis and body configurations. Knowing the body configuration of a truck (tank, van, platform) can indicate what commodity the truck carries. Knowing the commodity carried can indicate the type of activity taking place at a port, for example, by tracking the types of trucks coming in and out of the port. For this project, the lesson plans describe how to build a loop and use it to determine the different types of trucks coming in and out of an inland waterway port. Each lesson plan presents a scenario in which a critical transportation decision can be guided by knowledge of truck and commodity characteristics.

The Build Kit outreach program model expands on traditional outreach activities by introducing a train-the-trainer component, which provides training to transportation professionals on how to implement the build kits and their associated lesson plans. Incorporating train-the-trainer sessions ensures that the tool developed is useful to professionals, academics, and engineering students wishing to instruct a program. In the train-the-trainer sessions, lesson plans and presentation materials (slide decks and scripts) are provided along with survey material to determine if the outreach program had an effect of student interest in transportation engineering. The lesson plans include instructions on constructing an inductive loop, comparing graphical data representations, cleaning and using open-source code as a data source, analyzing investment scenarios, and preparing professional presentations. The questionnaire was based on the Student Attitudes toward STEM Survey[1] (S-STEM) developed at North Carolina State University. All lesson plan material is publicly available on the PI's website[2].

1.2 Background

1.2.1 Motivation

This project was motivated by the need to increase diversity in the transportation workforce. Diversity in the transportation planning and engineering workforce is critical for ensuring that transportation planning decisions reflect the unique and challenging needs of a diverse traveler population (Sorel and Theriault, 1993). However, women make up only 15% of the transportation workforce and have higher attrition rates largely driven by perceptions that the transportation industry does not emphasize communal goals, and that a lack of female role models and mentors exists (Godfrey and Bertini, 2019). Highlighting how the profession is congruent with women's desires for inclusive and communal environments can attract more women (Krome, 2016; Ivey et al., 2019), while engagement with professional organizations and having or serving as a role model can improve retention (Agrawal and Dill, 2008). Awareness of transportation topics at earlier stages of education (K-12) are important in workforce recruitment.

Anecdotal evidence from transportation professionals has led to the conclusion that many practicing professionals do not feel they have the resources to effectively conduct outreach on transportation topics in their communities. This is something the research team at the University of Arkansas has also experienced. While relatively equipped to handle elementary (K-5) programming, much more planning and time is needed to develop dynamic and meaningful programming for middle school, high school, and college-aged students. A study from Georgia Institute of Technology shows that students were much more excited about engineering outreach programming when technology was involved. These conversations with professionals and realizations from the local outreach community fed into the design and development of this outreach program to fulfill needs for the middle school and up age groups.

1.2.2 Background

During the National Transportation Workforce Summit in 2012, attendees identified lack of awareness as a major impediment to attracting future transportation professionals (*NWFS, 2012*). Moreover, a survey of undergraduate civil engineering students in an introductory transportation engineering course found that students were "relatively ignorant about the transportation engineering profession" and so did not specialize in the field (*Agrawal and Dill, 2008*). Considering that many students may be unaware of the diverse professions within the maritime transportation field, it is important to build an awareness of the profession to attract students to join the profession.

Active learning is one way to better link course content with students' motivation to study a subject while introducing transportation engineering concepts like transportation planning or other maritime transportation themes. Active learning moves beyond passive lecture style instruction by engaging students with hands-on experiences and interactions with the lecture content. Active learning can be as simple as an enhanced lecture where "clickers" or response tokens are used to engage students in lecture content or can take the form of more complex methods like using computer games, role-playing, service learning, or problem based learning **(Figure 1)**. Research suggests that methods such as service learning and problem based learning are a good model for reinforcing students' motivation to join a profession and/or persist in the degree programs and can have positive effects on minority students in particular

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[1] S-STEM Survey: https://miso.fi.ncsu.edu/articles/s-stem-survey

[2] Freight Transportation Data Research Lab Website: https://wordpressua.uark.edu/sarahvh

(*Tsang, 2000; Dewoolkar et al., 2009; Alpay et al., 2010; Turochy et al., 2013; Hernandez and Ritchie, 2015).*

Although there is evidence that active learning methods increase students' motivation to learn and can increase student retention, there is still a limited number of available educational materials to help educators introduce transportation topics at the middle and high school level. This implies that educators or others interested in engaging in outreach (such as professional engineers) need to develop their own lesson plans and activities- which can be a significant burden. Several universities and professional organizations are working to develop learning modules and activities for educators to use to introduce students to the transportation profession.

Researchers at the University of Minnesota developed a suite of outreach activities and lesson plans for K-12 students based on computer simulation games. Their module explores transportation engineering through an open-source computer simulation game called Gridlock Buster. These games were developed for K-12 curricula to be used by classroom teachers. The Institute of Transportation Engineers (ITE) has a suite of presentations and activities for download on a variety of topics most of which provide static content (e.g. PowerPoint slide decks) on the transportation engineering profession. Table 1 lists other institutions that have developed modules and interactive games related to transportation engineering and planning. However, none of the existing modules include maritime transportation concepts. In this project, we developed an educational module that introduces maritime transportation topics such a multi-modal supply chain performance in the context of transportation data collection. This provides a valuable resource for outreach to be used by professional organizations like ITE and MarTREC partners.

Table 1. Learning Module and Lab Example

Theme	Learning Module and Lab Examples
Campus Transit Lab (The Ohio State Univ.)	Development of an operating transit bus system into a living lab. (https://transitlab.osu.edu/campus-transit-lab-0)
Georgia Transportation Institute (Ga. Tech)	'Wheelchairs and Supershoes' learning module about measurements in transportation engineering. (http://transportation.ce.gatech.edu/node/54)
Center for Transportation Studies (University of Minnesota)	'Gridlock Buster' traffic control game based on tools and concepts used by traffic control engineers. (http://www.its.umn.edu/GridlockBuster/)
VT Scores Lab (Virginia Tech)	A suite of five game-aided educational modules for transportation engineering focusing on traditional transportation engineering concepts like geometric and pavement design. (https://www.vt-scores.cee.vt.edu/)
Institute of Transportation Engineers (ITE)	Transportation outreach and recruitment resources webpage includes presentations on a variety of transportation topics and activity sheets for K-12 and college programs. (http://www.ite.org/councils/education/recruitment/)

The ability to collect quality traffic data underpins most transportation planning and engineering tasks. For example, to develop an effective signal timing plan, it is standard practice to collect traffic volumes at each intersection approach during peak travel periods. Traffic data beyond traffic volumes are also needed to support transportation planning for passenger and freight traffic. Specifically, transportation planners seek origin-destination (OD) volumes and travel patterns to support travel demand model forecasting. While this data was historically collected through local and national travel surveys, it is becoming increasingly possible and common to collected OD data using passive tracking technologies. Examples of passive technologies include socially sourced data such as app-derived GPS tracking data and point-sensor based methods like automatic license plate readers, inductive loop detectors, and Bluetooth trackers.

The Traffic Sensor Build Kit outreach program integrates recommendations for active learning with emerging trends in traffic data collection. Moreover, the lesson plans designed in this project are modular meaning that components are interchangeable and can be easily adapted for different age groups. It will provide the tools necessary for early, hands-on exposure to technology and open-source code. Additionally, the program can be revised to highlight local transportation concerns for a state or city, providing students with insight to how their future careers make a local impact on their communities. Finally, this program is designed as a tool for transportation professionals to use for their outreach events. Train the trainer sessions can be organized by college students for transportation professionals during monthly lunch and learns or annual meetings. In this way, we promote two-way mentoring opportunities between college students and local transportation professionals.

1.3 Contribution

The Build Kits contribution to the academic community is to provide a dynamic outreach program that encompasses the breadth of the transportation profession by including maritime themes as well as transportation applications of other science, technology, engineering, and mathematical (STEM) disciplines. A program that is exciting to students by incorporating technology and allowing hands-on experience will serve to increase workforce development and awareness of the transportation industry. Additionally, this kit is designed intentionally to help meet the needs of the academic community by carefully including diverse characters in the lesson plans and by incorporating approachable computer coding opportunities. The Build Kits also include the technology that may be more difficult for schools or program instructors to come by, which are laptops and inductive sensing technologies. The Build Kits are designed to be scalable and useful for a variety of program types, lengths, and spaces. This allows instructors to be flexible with the needs of an after-school program or a summer camp, while still providing exciting and meaningful opportunities to engage students in transportation concepts. Finally, the Build Kits concept is to be an all-inclusive kit for easy portability to schools and organizations.

Providing complete and low-cost kits that relate traffic engineering concepts (e.g. freight data collection) to current and practical problems (i.e. measuring port performance or capturing truck movements) presents three contributions: (1) to the MarTREC program objectives, (2) to the first year engineering program, and (3) to the professional practice. First, the proposed outreach tools developed in this proposed work contribute to MarTREC's educational and outreach goals. Specifically, this project contributes to MarTREC's education and workforce development activities to "*develop instructional modules and case studies related to the engineering, logistics, and planning of maritime and multimodal transportation systems and practices*". Second, this work provides a unique tool to introduce students of various age groups to the multi-modal transportation planning field. As highlighted in the National Transportation Workforce Summit, more than 50% of the transportation workforce will retire over the next decade leaving significant knowledge and skills gaps (*NTWS, 2012*). Thus, it is critical to make students of every age aware of promising careers in the transportation field, especially those areas like maritime transportation planning that receive less attention in traditional engineering curricula. In addition to developing the lesson plans and build kits for middle and high school outreach programs hosted by the UofA, we propose to work with the UofA's first year engineering students enrolled in the UofA Freshman Engineering Program (FEP). The FEP is designed to help first year students build a solid foundation for their engineering education. This class introduces students to each of field of engineering study offered at the UofA through faculty lectures and group project activities.

2 Methodological Approach

This section reviews the approach taken to create the Build Kits. This includes the identification of discipline areas covered in the lesson plans, selection of components for the kits, development of lesson plan slide decks and scripts, and use of evaluation surveys.

2.1 Approach

2.1.1 Discipline Identification

The Build Kits were developed by first assessing disciplines that were critical to dynamic transportation engineering concepts. With consideration of the maritime theme along with increasing technology accessibility and awareness among students, the following emphasis areas were identified:

(1) transportation engineering,
(2) computer engineering,
(3) coding, and
(4) data analytics.

These are the four primary categories that served as the foundation of the Build Kits and the components and lesson plans included therein.

2.1.2 Component Selection

Having identified the critical disciplines that should be included in outreach programming, individual components were identified for the Kit. General specifications for the Kit were for low-cost, commercially and readily available technology components and either open source or commonly used software. For associated lesson plans, hands-on activities were critical, but outdoor activities (e.g., counting vehicles, visiting an intersection, etc.) should be avoided to limit risk and improve transferability to other regions/cities/areas.

After considering Bluetooth, Lidar, and Inductive loop technologies, the final kit includes a small scale (≥12 in diameter) inductive loop and detector card. Unlike Bluetooth data collection which would require students to travel outside the classroom, data from the mini loop can be collected using toy cars/trucks in a classroom setting. Low-cost Lidar sensors were too unstable to use in this application. The mini inductive loop and detector card can be used to detect differences in truck body configurations (tank, van, platform, dump, etc.). Truck body configurations can be tied to the types of commodities moving in and out of an inland waterway port and thus provide a segue into maritime transportation planning topics. The computer engineering discipline is incorporated when students identify components of and construct the inductive loop sensor. Open-source code is used to sort and count trucks from different body-style characteristics. This requires a dataset generated by the inductive loop detector and a text editor. Finally, the data analytics discipline is incorporated by having students use the data generated by the loop to make investment decisions regarding competing transportation projects. This requires commonly used software including Microsoft Excel and Microsoft PowerPoint.

All components are commercially available through Amazon or other similar retailers. The total estimated cost of one kit is approximately $450 (**Table 2**). Components included (**Figure 1**):

(1) Low-cost laptop (≥$250) with USB port
(2) Inductive wire (copper wire), foam loop form, and jumper wires (for power)

(3) Inductive loop detector card and power adapter
(4) Toy trucks of different types
(5) Various tools (small screwdriver and tape)
(6) Thumb drive (USB) with software
(7) Plastic tote for organizing components

The sensor detector card used in the Build Kits is approximately the size of a Raspberry Pi. The inductive loop detector card used in the Build Kit (**Figure 2**) is available from Tindie[3]. Instructions and videos on how to use the detector card are available on Elektronika[4]. It consists of two layers – a power board and a switch board and is encased in a transparent plastic shell where sensing lights and other features can be observed externally by students.

Figure 1. Build Kit Components

[3] Tindie: https://www.tindie.com/products/elektronika_ba/dual-channel-inductive-loop-vehicle-detector/
[4] Elektronika: https://www.elektronika.ba/868/dual-channel-inductive-loop-vehicle-detector/

Table 2. Build Kit Component List and Prices

Item	Cost per Item
Plastic tote	$15.00
Chromebook & Charger	$188.00
Inductive Sensor + Wire Adapter	$142.00
USB to Mini-USB Cable (3 Pack)	$3.00
Jumper Wires (120 pack, 7.8 inches)	$6.00
Copper Wire (Insulated)	$8.47
Loop Base (foam)	$2.00
Electrical Tape	$1.50
Screwdriver	$1.00
Toy Truck - W900 (Dry Fertilizer example)	$30.00
Toy Truck - International Lonestar (Sand trailer example)	$30.00
Flashdrive (USB Thumb Drive)	$3.00
Power Adapter	$11.00
Total for one Build Kit	**$440.52**

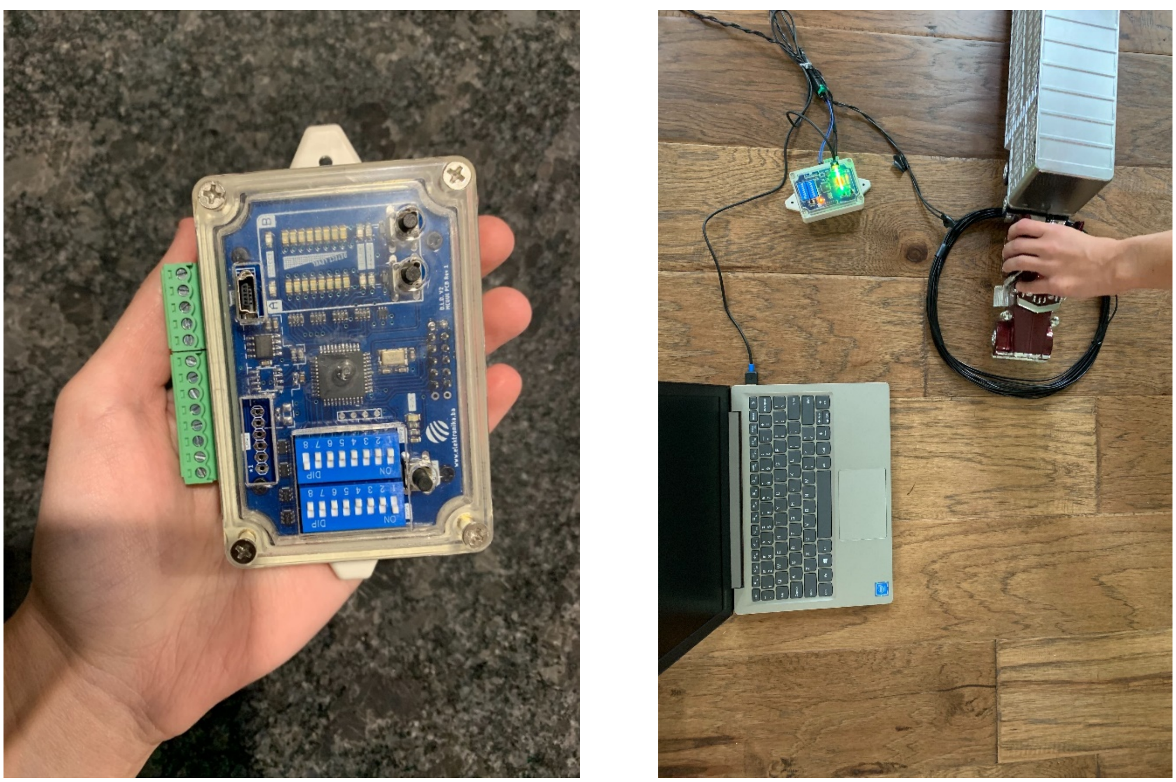

Figure 2. Inductive Detector Card (left) and example of a toy truck moving over the mini-loop (right)

The software that accompanied the inductive sensors allows users to change loop sensitivity settings and to generate a graph of the sensor's frequency when the presence of metal is detected over the inductive loop (**Figure 3**). These graphs are used to differentiate between truck body style characteristics. Software (open-source) to tune the sensor and view and download sensor output is available from GitHub (https://github.com/elektronika-ba/dual-loop-detector-configurator).

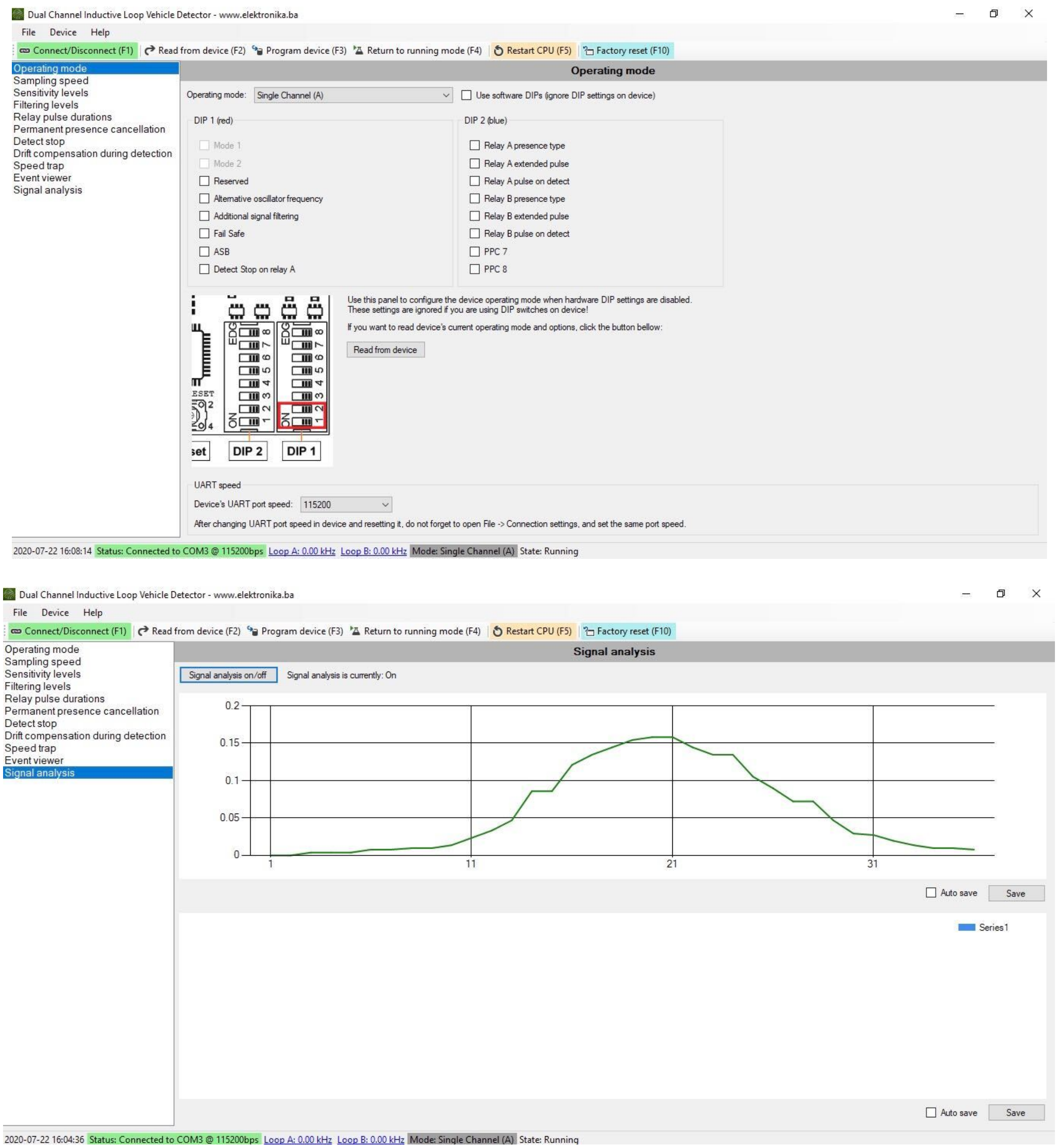

Figure 3. Inductive Loop Detector Card Software Interface parameters (top) and detector read out (bottom).

2.1.3 Lesson Plan Development

In addition to the previously listed components, the Build Kits also include lesson plans and corresponding presentations and scripts for the instructor to use. These lesson plans reinforce concepts from the literature review such as including diversity in engineering roles as well as offering various local scenarios that take students' intrinsic motivations and values into consideration throughout the program. For example, a scenario will have the students sort fertilizer trucks from other types of trucks to compare alternate highway investments for the routes serving a port and a local blueberry farm (**Figure 4,** *next page*). Another scenario has students sort trucks by body characteristics and determine and compare the capacity of two ports that serve the City of Jonesboro, Arkansas after a severe tornado.

The lesson plans introduce the concept of an inland waterway port, detail logistics and discuss types of commodities that are delivered via the waterways. The plans would discuss the commodities' transfer to trucks or train and then how the commodities are distributed throughout the state, for example. The scenario would then be introduced, the inductive loop would be built, truck types would be sorted, and commodities counted. The data would then be analyzed to answer a specific question or to prioritize investment or logistics decisions. Figures 5 and 6 are sample slides from the presentation that accompany the lesson plans.

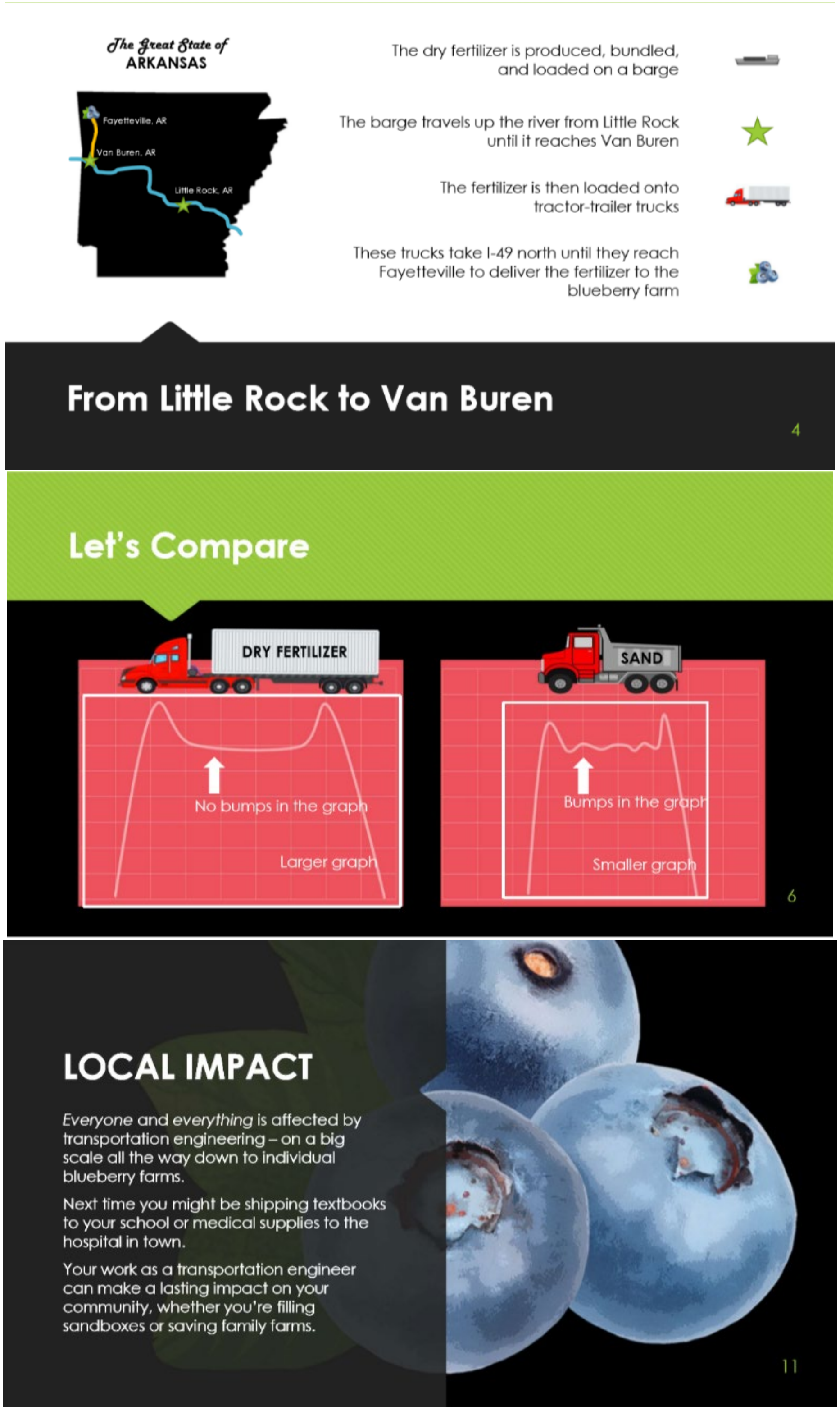

Figure 4. Examples of Lesson Plan Slides for Blueberry Farm scenario. Description of alternate routes between Blueberry farm and Port of Van Buren for fertilizer trucks (top). Comparison of inductive loop signatures for different truck types (middle). Explanation of local impact of transportation decisions (bottom).

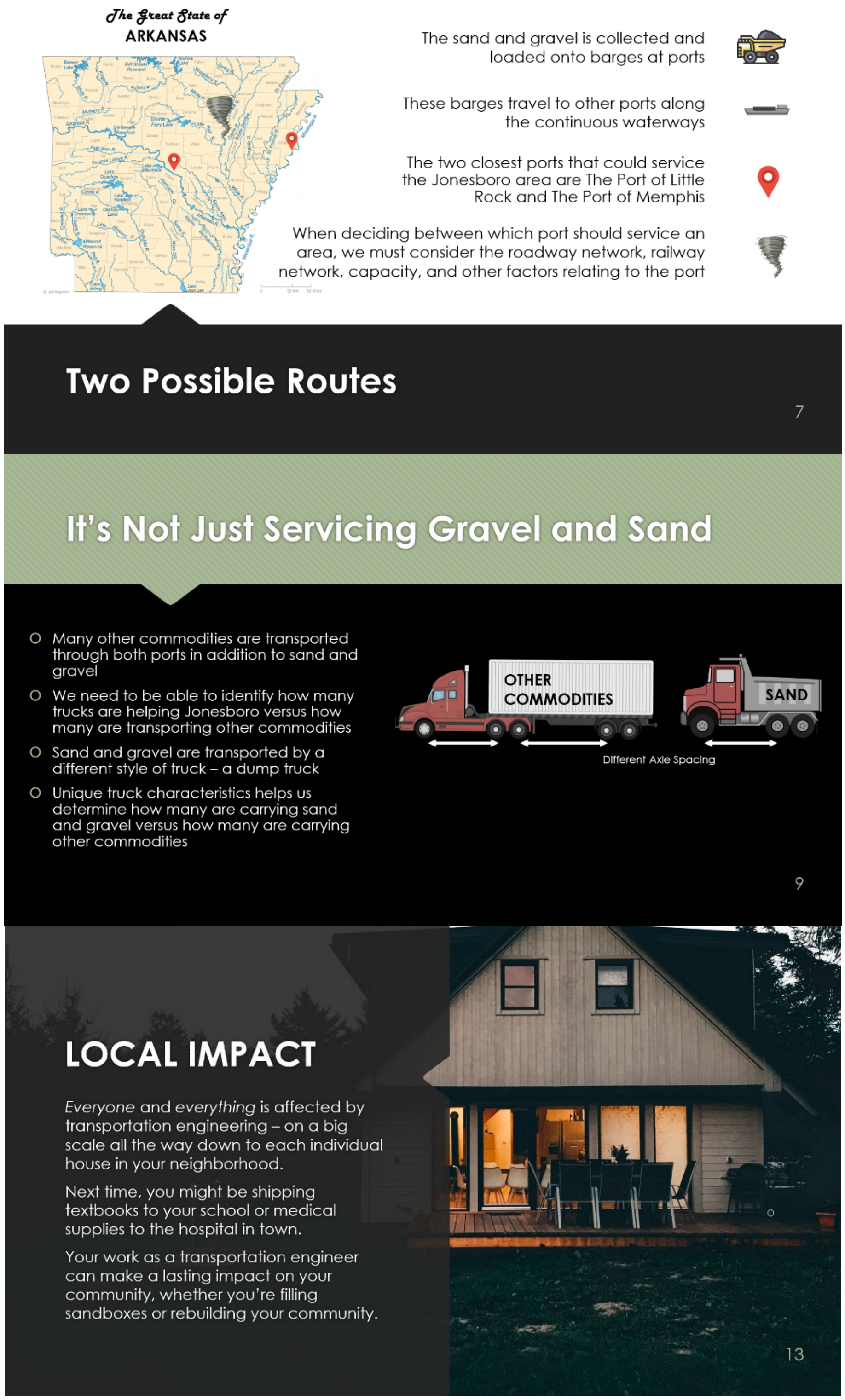

Figure 5. Example of Lesson Plan Slides for Jonesboro Tornado Scenario. Description of alternate routes to Jonesboro (top). Comparison of truck body style characteristics affecting truck signatures (middle). Explanation of local impact of transportation decisions (bottom).

2.1.4 Evaluation Tools

To evaluate the outreach program, pre- and post-assessment surveys have been modified from STEM outreach efforts curated by North Carolina State University's (NCSU) Friday Institute. These surveys can be found in Appendix A. The surveys include questions regarding the students' backgrounds, parents' education levels, the students' accessibilities to technology, as well as their interests in or disregard for STEM-related concepts and topics. It also assesses to what extent they learned from the outreach program itself and whether they are more- or less-inclined to pursue topics such as transportation engineering in the future. Two sample questions from each question category can be explored in **Figure 5**. The complete survey for middle and high school students can be found in Appendix B.

Category	Questions
Math	I would consider choosing a career that uses math. I can handle most subjects well, but I cannot do a good job with math.
Science	I expect to use science when I get out of school. I will need science for my future work.
Engineering & Technology	I like to imagine creating new products. I believe I can be successful in a career in engineering.
21st Century Learning	I am confident I can produce high quality work. I am confident I can include others' perspectives when making decisions.
About Yourself	How well do you expect to do this year in your (1) English/Language Arts Class, (2) Math Class, (3) Science Class? Do you plan to go to college?

Figure 6. Question examples taken from the S-STEM Survey produced by North Carolina State University's Friday Institute

2.3 Lesson Plan Overview

Lesson plans were curated for two age groups: (1) Middle School + and (2) High School +. The age-specific lesson plans provide meaningful programming while considering age-appropriate skill sets and experience. Overviews of the lesson plans can be found in **Appendices A-1 and A-2.**

2.3.1 Introduction to Inductive Loops

The first lesson included in the Build Kit is an introduction to inductive loop technology (**Figure 7**) that is used for all age groups at the onset of the program. The lesson provides background on traffic sensing technologies, including the types of sensing technologies available, as well as the advantages or disadvantages of each. There are seven slides in this deck and the expected delivery time is 10 minutes. By the end of the lesson, students should be able to:

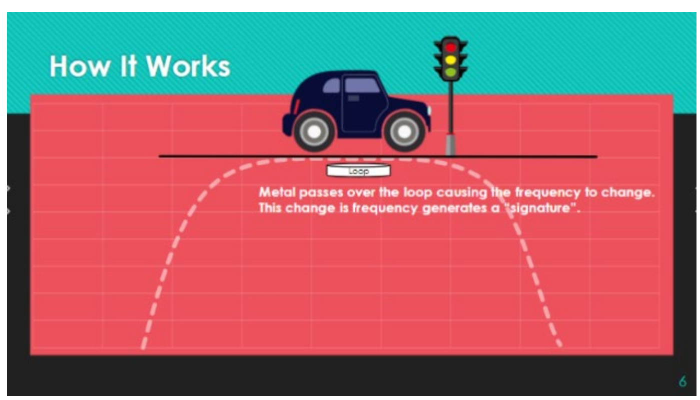

Figure 7. How Loops Work Slide Example for Introduction to Loop Detection Technology

(1) Differentiate between manual, fixed time, and actuated signal control
(2) Describe the role of inductive loops in actuated signal control
(3) State how inductive loops can be used to classify vehicles

2.3.2 Middle School +

The first scenario was curated for the middle school + (i.e., middle school or older) age group with regards to language and concepts used as well as the coding and graphical expectations. In this scenario, the O'Connor family needs fertilizer for their historical family blueberry farm in Fayetteville, Arkansas. The students watch a video explaining port operations to understand how commodities move through the waterways. Then a second commodity coming through The Port of Van Buren is introduced: sand. The style of trucks carrying both commodities is depicted along with graphical representations of each truck body style. The students are given an investment opportunity from Arkansas Department of Transportation (ARDOT) in which $30 million is to be invested in one of two highways servicing the Port of Van Buren. If one highway is servicing the dump-trucks full of sand while the other highway is servicing the tractor-trailers carrying dry fertilizer, students must build an inductive loop and use a simple dataset to determine where to invest the money from ARDOT. There are 12 slides in this deck and the expected delivery time is 15 minutes with 20-30 minutes for the activity. By the end of the lesson, students should be able to:

Figure 8. Meet the Diaz Family Slide Example for Middle School + Lesson Plan

(1) Identify the role of transportation investments in serving local communities,
(2) Interpret data from sensor outputs to draw conclusions about transportation activity, and
(3) Analyze alternate investment scenarios using observed data.

2.3.3 High School +

The second scenario was curated for high school and first-year college students with regards to language and concepts used as well as coding and graphical expectations. In this scenario, the City of Jonesboro, Arkansas needs more sand and gravel to rebuild the city after a severe tornado in the Spring of 2020. The students watch a video explaining port operations about transporting aggregate and to better understand how commodities move through the waterways. The students are introduced to the concept of graphical representations of various vehicle characteristics. After building an inductive loop, students are given a dataset where they are required to count a variety of truck types, then determine which of two ports is operating at, above, or below capacity. This will inform which port should service the Jonesboro area with the aggregate needed to rebuild the city. There are 13 slides in this deck and the expected delivery time is 20 minutes with 20-30 minutes for the activity. By the end of the lesson plan, students should be able to

Figure 9. Meet the Bower Family Slide Example from High School + Lesson Plan

(1) Understand factors that limit the use or efficiency of port operations,
(2) Interpret data from sensor outputs to draw conclusions about transportation activity, and
(3) Analyze alternatives using concepts of port capacity.

2.3.4 Building the Inductive Loop

The final lesson plan goes through the steps with detailed photographs of how to build the inductive loop and configure the sensor for vehicle detection. This is the first step of determining the answers to each of the investment scenarios for various age groups and provides additional guidance and support to the program instructor. There are seven slides in this deck and the expected delivery time is 30 minutes including activities (this activity takes place as part of the above lesson plans). By the end of the lesson, students should be able to:

(1) Identify components of inductive loop detectors
(2) Devise experimental testing procedures to find optimal sensor parameters
(3) Relate sensor outputs to inputs (truck types)

2.4 Evaluation

The intent of the research team for this project was to implement the pre- and post-assessment surveys from The Friday Institute before and after implementation of this outreach program at GirlTREC 2020 at the University of Arkansas. Currently, COVID-19 has prevented implementation efforts hindering the ability of the research team to analyze the survey results to form an intentional survey for the program or to further evaluate program effectiveness. Currently, the team plans to move forward with the implementation and evaluation stages into Fall 2020 or later, as necessary. Questions to be included in the survey are provided in **Appendix B**.

3 Conclusions

The purpose of this project was to develop learning modules that introduce students to new transportation data collection technologies that can be applied to better understand inland waterway port activity. We developed a low-cost traffic sensor build kit that includes a mini inductive loop detector, detector card, and laptop. To accompany the build kit, we created lesson plans for (i) how loops function, (ii) how to build a loop, and (iii) two additional lesson plans with targeted activities for middle and high school students.

Each lesson plan includes a colorful slide presentation that features a scenarios of port investment prioritization with examples local to Arkansas. Six complete build kits were assembled and in future work will be shared with summer camps at the UA and with professional transportation groups for outreach events. With its scalable components, the build kits are quickly adaptable to a variety of program types, lengths, and spaces, making the learning experience customizable to suit the needs of the local schools and summer programs. All presentation materials are included on the PI's website (http://wordpressua.uark.edu/sarahvh).

Due to project interruptions resulting from Covid-19, we were unable to test the build kits during planned summer programs and thus were not able to have students complete assessment surveys to measure the impact of our materials. We adapted STEM surveys from ongoing NSF projects for use with out project. These surveys can help to gauge how the lesson plans affected students' knowledge and interest in transportation planning, engineering, and inland waterway related careers. In the future, we plan to carry out the lesson plans on middle and high school students and will continue to refine the lesson plans and activities.

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Appendix A: Lesson Plan Scenario Overviews

A-1: Middle School +

Scenario Overview
A local, family-owned blueberry farm is in need of fertilizer. After learning how dry fertilizer is bundled and transported, a local port is identified that the fertilizer would be delivered at. The barge-to-trailer transition is explained. This portion offers students real-world applications of traffic sensing technologies and appeals to potential intrinsic motivations they may have. Another commodity that travels through the local port is identified. The lesson plan then examines the truck body characteristics that would be likely to carry each commodity from the port. Students learn what the signatures of each truck body style would look like and are then presented with a data set. This data set includes data for each of the two trucks as well as passenger cars. Students will be led through a process included cleaning the data and then using open-source code to sort and count the number of trucks and identify their locations throughout the state. Students will be presented with two investment opportunities and must select the best option given their data set. Each investment opportunity makes an improvement upon port operations or transporting commodities from the port to the local community. Students will then be guided using data visualization tools such as creating graphs and pie charts to use in a presentation at the end of the lesson. In this presentation, they will discuss the data set they had, why they chose a particular investment opportunity over the other and support their claims with graphical representations of their data set.

Resources
Please visit https://wordpressua.uark.edu/sarahvh where a dedicated page will contain all lesson plan materials.

A-2: High School +

Scenario Overview

The City of Jonesboro, Arkansas needs more sand and gravel to rebuild the city after a severe tornado in the Spring of 2020. The students watch a video explaining port operations regarding transporting aggregate and to better understand how commodities move through the waterways.

The students are then explained the concept of graphical representations of various vehicle characteristics.

After building an inductive loop, students are given a dataset where they are required to count a variety of truck types, then determine whether each of two ports is operating at, above, or below capacity. This will inform which port should service the Jonesboro area with the aggregate needed to rebuild the city.

Students will then be guided through the application of data visualization tools such as creating graphs and pie charts to use in a presentation at the end of the lesson. In this presentation, they will discuss the data set they had, why they chose a particular investment opportunity over the other and support their claims with graphical representations of their data set.

Resources

Please visit https://wordpressua.uark.edu/sarahvh where a dedicated page will contain all lesson plan materials.

Appendix B: Surveys

Student Attitudes Toward STEM (S-STEM) Survey

Middle and High School Students (6-12th grades)

Last Updated March 2014

Appropriate Use
The Middle/High School (6-12th) S-STEM Survey is intended to measure changes in students' confidence and efficacy in STEM subjects, 21st century learning skills, and interest in STEM careers. The survey is available to help program coordinators make decisions about possible improvements to their program.

The Friday Institute grants you permission to use these instruments for educational, noncommercial purposes only. You may use an instrument as is, or modify it to suit your needs, but in either case you must credit its original source. By using this instrument you agree to allow the Friday Institute to use the data collected for additional validity and reliability analysis. The Friday Institute will take appropriate measures to maintain the confidentiality of all data.

Recommended citation for this survey:
Friday Institute for Educational Innovation (2012). *Student Attitudes toward STEM Survey-Middle and High School Students*, Raleigh, NC: Author.

The development of this survey was partially supported by the National Science Foundation under Grant No. 1038154 and by The Golden LEAF Foundation.

The framework for part of this survey was developed from the following sources:

Erkut, S., & Marx, F. (2005). *4 schools for WIE* (Evaluation Report). Wellesley, MA: Wellesley College, Center for Research on Women. Retrieved April 5, 2012 from http://www.coe.neu.edu/Groups/stemteams/evaluation.pdf

Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook*, 2010-11 Edition.

DIRECTIONS:

There are lists of statements on the following pages. Please mark your answer sheets by marking how you feel about each statement. For example:

Example 1:	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I like engineering.	○	○	○	○	○

As you read the sentence, you will know whether you agree or disagree. Fill in the circle that describes how much you agree or disagree.

Even though some statements are very similar, please answer each statement. This is not timed; work fast, but carefully.

There are no "*right*" or "*wrong*" answers! The only correct responses are those that are true *for you*. Whenever possible, let the things that have happened to you help you make a choice.

PLEASE FILL IN ONLY ONE ANSWER PER QUESTION.

Math

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1. Math has been my worst subject.	○	○	○	○	○
2. I would consider choosing a career that uses math.	○	○	○	○	○
3. Math is hard for me.	○	○	○	○	○
4. I am the type of student to do well in math.	○	○	○	○	○
5. I can handle most subjects well, but I cannot do a good job with math.	○	○	○	○	○
6. I am sure I could do advanced work in math.	○	○	○	○	○
7. I can get good grades in math.	○	○	○	○	○
8. I am good at math.	○	○	○	○	○

Science

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
9. I am sure of myself when I do science.	○	○	○	○	○
10. I would consider a career in science.	○	○	○	○	○
11. I expect to use science when I get out of school.	○	○	○	○	○
12. Knowing science will help me earn a living.	○	○	○	○	○
13. I will need science for my future work.	○	○	○	○	○
14. I know I can do well in science.	○	○	○	○	○
15. Science will be important to me in my life's work.	○	○	○	○	○
16. I can handle most subjects well, but I cannot do a good job with science.	○	○	○	○	○
17. I am sure I could do advanced work in science.	○	○	○	○	○

Engineering and Technology

Please read this paragraph before you answer the questions.

Engineers use math, science, and creativity to research and solve problems that improve everyone's life and to invent new products. There are many different types of engineering, such as chemical, electrical, computer, mechanical, civil, environmental, and biomedical. Engineers design and improve things like bridges, cars, fabrics, foods, and virtual reality amusement parks. **Technologists** implement the designs that engineers develop; they build, test, and maintain products and processes.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
18. I like to imagine creating new products.	○	○	○	○	○
19. If I learn engineering, then I can improve things that people use every day.	○	○	○	○	○
20. I am good at building and fixing things.	○	○	○	○	○
21. I am interested in what makes machines work.	○	○	○	○	○
22. Designing products or structures will be important for my future work.	○	○	○	○	○
23. I am curious about how electronics work.	○	○	○	○	○
24. I would like to use creativity and innovation in my future work.	○	○	○	○	○
25. Knowing how to use math and science together will allow me to invent useful things.	○	○	○	○	○
26. I believe I can be successful in a career in engineering.	○	○	○	○	○

21st Century Learning

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
27. I am confident I can lead others to accomplish a goal.	○	○	○	○	○
28. I am confident I can encourage others to do their best.	○	○	○	○	○
29. I am confident I can produce high quality work.	○	○	○	○	○
30. I am confident I can respect the differences of my peers.	○	○	○	○	○
31. I am confident I can help my peers.	○	○	○	○	○
32. I am confident I can include others' perspectives when making decisions.	○	○	○	○	○
33. I am confident I can make changes when things do not go as planned.	○	○	○	○	○
34. I am confident I can set my own learning goals.	○	○	○	○	○
35. I am confident I can manage my time wisely when working on my own.	○	○	○	○	○
36. When I have many assignments, I can choose which ones need to be done first.	○	○	○	○	○
37. I am confident I can work well with students from different backgrounds.	○	○	○	○	○

Your Future

Here are descriptions of subject areas that involve math, science, engineering and/or technology, and lists of jobs connected to each subject area. As you read the list below, you will know how interested you are in the subject and the jobs. Fill in the circle that relates to how interested you are.

There are no "*right*" or "*wrong*" answers. The only correct responses are those that *are true for you.*

	Not at all Interested	Not So Interested	Interested	Very Interested
1. **Physics:** is the study of basic laws governing the motion, energy, structure, and interactions of matter. This can include studying the nature of the universe. *(aviation engineer, alternative energy technician, lab technician, physicist, astronomer)*	○	○	○	○
2. **Environmental Work:** involves learning about physical and biological processes that govern nature and working to improve the environment. This includes finding and designing solutions to problems like pollution, reusing waste and recycling. *(pollution control analyst, environmental engineer or scientist, erosion control specialist, energy systems engineer and maintenance technician)*	○	○	○	○
3. **Biology and Zoology:** involve the study of living organisms (such as plants and animals) and the processes of life. This includes working with farm animals and in areas like nutrition and breeding. (*biological technician, biological scientist, plant breeder, crop lab technician, animal scientist, geneticist, zoologist)*	○	○	○	○
4. **Veterinary Work:** involves the science of preventing or treating disease in animals. *(veterinary assistant, veterinarian, livestock producer, animal caretaker)*	○	○	○	○
5. **Mathematics:** is the science of numbers and their operations. It involves computation, algorithms and theory used to solve problems and summarize data. *(accountant, applied mathematician, economist, financial analyst, mathematician, statistician, market researcher, stock market analyst)*	○	○	○	○

	Not at all Interested	Not So Interested	Interested	Very Interested
6. **Medicine:** involves maintaining health and preventing and treating disease. *(physician's assistant, nurse, doctor, nutritionist, emergency medical technician, physical therapist, dentist)*	○	○	○	○
7. **Earth Science:** is the study of earth, including the air, land, and ocean. *(geologist, weather forecaster, archaeologist, geoscientist)*	○	○	○	○
8. **Computer Science:** consists of the development and testing of computer systems, designing new programs and helping others to use computers. *(computer support specialist, computer programmer, computer and network technician, gaming designer, computer software engineer, information technology specialist)*	○	○	○	○
9. **Medical Science:** involves researching human disease and working to find new solutions to human health problems. *(clinical laboratory technologist, medical scientist, biomedical engineer, epidemiologist, pharmacologist)*	○	○	○	○
10. **Chemistry:** uses math and experiments to search for new chemicals, and to study the structure of matter and how it behaves. *(chemical technician, chemist, chemical engineer)*	○	○	○	○
11. **Energy:** involves the study and generation of power, such as heat or electricity. *(electrician, electrical engineer, heating, ventilation, and air conditioning (HVAC) technician, nuclear engineer, systems engineer, alternative energy systems installer or technician)*	○	○	○	○
12. **Engineering:** involves designing, testing, and manufacturing new products (like machines, bridges, buildings, and electronics) through the use of math, science, and computers. *(civil, industrial, agricultural, or mechanical engineers, welder, auto-mechanic, engineering technician, construction manager)*	○	○	○	○

About Yourself

DIRECTIONS: In the following series of questions, you will skip certain questions based on how you answered previous questions.

1. How well do you expect to do this year in your:

	Not Very Well	OK/Pretty Well	Very Well
English/Language Arts Class?	○	○	○
Math Class?	○	○	○
Science Class?	○	○	○

2. In the future, do you plan to take advanced classes in:

	Yes	No	Not Sure
Mathematics?	○	○	○
Science?	○	○	○

3. Do you plan to go to college?
- ❍ Yes
- ❍ No
- ❍ Not Sure

Displayed only if answer to Question 3 was "Yes."

4. If so, please list what college(s) you are interested in attending.

____

Displayed only if answer to Question 3 was "Yes."

5. Are you planning on going to a community college or four-year college/university first?
- ❍ Community College
- ❍ Four-year College

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