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STRIDE | Southeastern Transportation Research, Innovation, Development and Education Center

Final Report

LEGO Robot Vehicle Afterschool Workshops: Transportation Engineering Problem Solving

(Year 1 & 2)

James B. Martin, PE, MCE, PI North Carolina State University
Nancy R. Bailey, MLS, North Carolina State University

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DISCLAIMER

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ABSTRACT

"LEGO® Robot Vehicle Lesson Plans for Secondary Education – A Recruitment Tool for Transportation Engineering" was a workforce development project that was used to introduce students at the middle school level to congestion mitigation solution research, describing the importance of modeling and assessment of advanced technologies and Intelligent Transportation Systems (ITS) with respect to congestion mitigation; and improvements of traffic signal systems to reduce delays in urban corridors.

Students used computers, basic computer programming, mathematics, and robots as tools. They were introduced to transportation engineering as a career and were shown how STEM subjects apply to the field. Through the material presented in the lesson plans, the students developed an understanding of the work involved in transportation engineering. The lesson plans were used to show the students how transportation affects society as a whole and teach them how the use of advanced technology is integral to solving current and future transportation problems. Students were able to relate what they were learning about technology and engineering through hands-on exercises that employed elements of math and science.

This workforce development project was funded for two years (2012 and 2013).

EXECUTIVE SUMMARY

The Center for Transportation and the Environment at North Carolina State University collaborated with the University of Florida to implement workforce development workshops for children at the middle school level in North Carolina through a program titled, LEGO® Robot Vehicle Afterschool Workshops: Transportation Engineering Problem Solving. The primary focus of this program was to increase STEM awareness and introduce middle school students to the field of transportation engineering. This program connects learning to the real world by utilizing elements of math and science in the programming of LEGO® robot vehicles. The robot vehicles also illustrate the relationship of the technology involved in intelligent transportation systems to finding solutions to congestion mitigation. This workforce development project was funded for two years (2012 and 2013).

CTE worked with the Centennial Campus Magnet Middle School on the campus of NC State to introduce the lesson plans to eleven students identified by the resource teacher at the school. CTE staff and a civil engineering graduate student at NC State presented the lessons to the middle school students.

In the first session, students were given a pre-test to determine their level of knowledge with the subject matter. They were introduced to the field of transportation engineering as well as to congestion mitigation and intelligent vehicles. Subsequent lessons introduced the students to the basic operation of the LEGO robots and associated software. Tutorials related the programming of the robots to scenarios involving congestion and how intelligent vehicles could be used to mitigate problems related to congestion. Students constructed programs using the software and then downloaded them to the robot vehicle for testing. They evaluated and refined their programs based on the outcome of their testing.

Between lessons, students were given an opportunity to discuss what they had learned and provided examples of problems they encountered and how they solved them. At the end of the last session, students were given a post-test.

The students were engaged in the workshop and asked relevant questions pertaining to the subject matter. As they progressed through the tutorials, they saw that there were many approaches to problem solving. They became more confident and started to program the robots to do more than was required.

Additionally, this project provided outreach to **134 students** in the Graham County School System in Year 2 (2013). Graham County is an economically distressed county in western North Carolina which does not have a significant supply of engineers to serve as mentors and ranks at or near the top of the list of counties for highest unemployment in the state.

By relating the programming of robot vehicles to a common traffic problem such as congestion, the students gained insight as to how transportation engineers can use technology to mitigate the impact that transportation problems have on society.

CHAPTER 1 BACKGROUND

PROBLEM STATEMENT

The United States Department of Labor predicted that job growth for civil engineers will be above average - about 24 percent over the next decade (1). Spurred by general population growth and its impact on transportation infrastructure, demand for transportation engineers is expected to increase. Transportation is vital to job growth and economic development at the state and regional level. In order to retain a competitive edge, it is imperative to get young people interested in engineering and to promote the field as a viable and exciting career path where they can have a positive impact.

For many years, children have been enjoyed playing with LEGOs. LEGOs have grown up and a new generation of children will have an opportunity to learn the basic principles of engineering using LEGO® Mindstorms NXT robots – robots that can see, speak, feel, and move

RESEARCH OBJECTIVE

The Center for Transportation and the Environment (CTE) at North Carolina State University collaborated with the University of Florida to implement workforce development workshops for children at the middle school level in Raleigh, North Carolina. This program, "LEGO® Robot Vehicle Afterschool Workshops: Transportation Engineering Problem Solving," provided a hands-on experience to encourage this age group to get excited about science, technology, engineering, and math (STEM) topics and foster interest in transportation engineering as a career choice. This program connects learning to the real world by using the

LEGO® robot vehicles and finding solutions to congestion mitigation. Additionally, the students are introduced to transportation engineering as a viable career option.

SCOPE OF STUDY

CTE used the "LEGO® Robot Vehicle Lesson Plans for Secondary Education – A Recruitment Tool for Transportation Engineering" developed by the Transportation Technology Transfer (T2) Center in the Department of Civil and Coastal Engineering at the University of Florida and implemented it in North Carolina as a K-12 workforce development activity.

The lesson plans introduced the students, at their level, to the congestion mitigation solution research priority for recurrent congestion, describing the importance of modeling and assessment of advanced technologies and Intelligent Transportation Systems (ITS) with respect to congestion mitigation; and improvements of traffic signal systems to reduce delays in urban corridors.

Students were exposed to computers; basic computer programming; mathematics, as it relates to the tasks; and robots as tools. Students were taught some fundamentals of transportation engineering and how the use of advanced technology is integral to solving current and future transportation problems. They were also taught how transportation affects the quality of life in our society.

CHAPTER 2 RESEARCH APPROACH

The primary focus of this workforce development program was to increase STEM awareness and introduce middle school students to the field of transportation engineering. The curriculum was developed at the University of Florida for the purpose of introducing middle school students to transportation engineering and showing them how transportation impacts their every-day lives. The lesson plans introduced the concept of using ITS to assist in the mitigation of traffic congestion. The Robot Vehicle Course material may be obtained via http://stride.ce.ufl.edu/lego-robotics-vehicle-lesson-plans-for-secondary-education.

CTE worked with the Academically/Intellectually Gifted (AIG) resource teacher at Centennial Campus Magnet Middle School (CCMMS) on the campus of North Carolina State University to identify students with an interest in STEM subjects. CTE introduced the lesson plans to eleven students at CCMMS for a three-day after school workshop located in one of the classrooms at the school. These workshops, which consisted of three lessons at two hours each, were held October 9-11, 2013 (Year 1) and December 8-14, 2014 (Year 2) CTE staff and a civil engineering graduate student at NC State presented the lessons to the middle school students. Nine of the students were seventh grade; two were sixth grade.

Figure 2-1. Students construct a program using the LEGO® educational software.

Interpersonal and communication skills were stressed as students were divided into four teams. They were given tutorials that presented scenario problem statements to work on throughout the sessions. Combined with PowerPoint presentations and demonstrations, students worked hands-on with pre-built LEGO® NXT Intelligent Vehicles and LEGO® education software (see Figure 2-1). Measurement criteria in the lesson plans consist of pre- and post-tests, lesson review worksheets, and mini assessments.

The original lesson plans were written for five 1-1/2 hour after school sessions totaling 7-1/2 hours. Due to scheduling issues, the original lesson plans were edited to fit the six hour timeframe available. Since the time was condensed, the lesson review worksheets and the mini assessments were not needed and were replaced by a question and answer review at the beginning of the each lesson. All of lesson one and all of the LEGO® robot programming activities were completed as well as the Pre- and Post-Course Questionnaires.

The first session provided the students with an introduction to the field of transportation engineering. A transportation engineer presented the material about his education and career and introduced the topic of congestion by relating it to the Raleigh area. He introduced the concept of intelligent vehicles and engaged the students in a conversation about problems caused by congestion and asked for examples of how congestion had impacted their lives.

Subsequent sessions introduced the students to the activities involving the LEGO® robots. Tutorials were used to relate the programming of the robots to congestion mitigation. Students used the software to construct the programs which they then downloaded to the robot vehicles. They tested their programs as illustrated in Figure 2-2 and made adjustments to the programs as needed.

The students asked relevant questions throughout the sessions and made appropriate comments on the subject matter. As the students worked through the tutorials in the lesson plans, they acknowledged that there were many approaches to problem solving and were observed incorporating the advice of other team members into their problem solutions. As they progressed in the lessons, they became more confident and started to program the robots to do more than was required in the tutorial.

Additionally, in Year 2 of this project, the CTE worked with 134 students at Robbinsville High School in Graham County, North Carolina. Nine sessions were offered for a total of 13 hours in which students were introduced to careers in transportation as well as learning practical math applications. Curriculum topics covered included introductions to calculus, physics, parabolic equations, and quadratic formulas. Transportation engineering topics included operations, safety, and highway design. LEGO robot vehicles were used to demonstrate the concepts presented. In addition to math concepts, the LEGO robot vehicles were included in discussions of the future of technology in the roadway environment, from incremental vehicular design improvements to fully-automated vehicles.

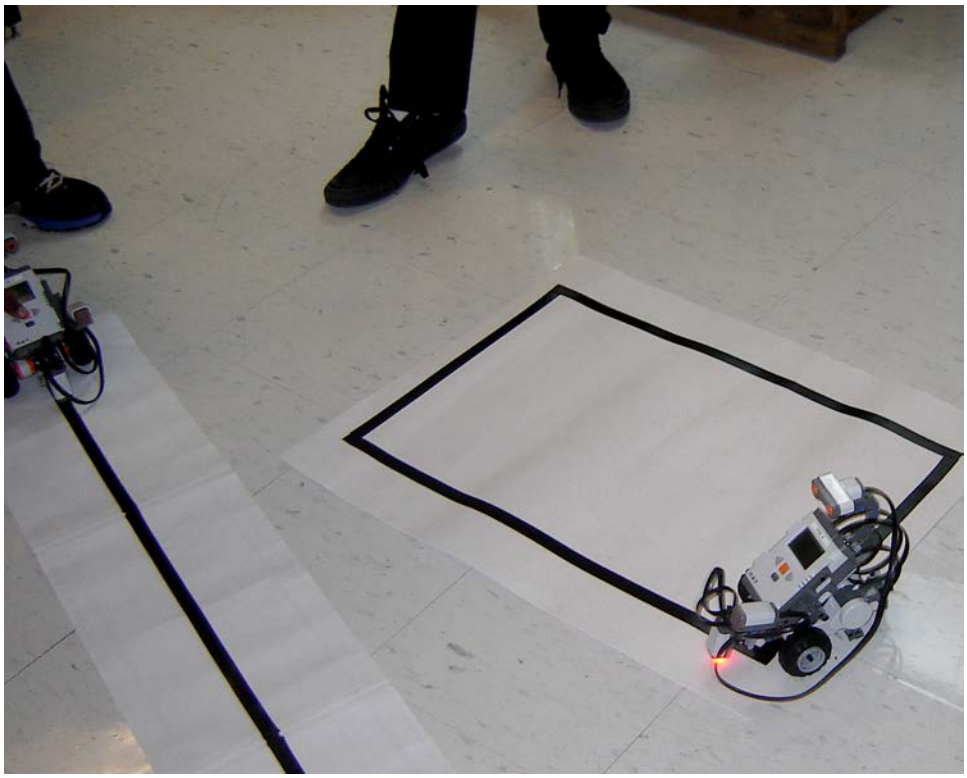

Figure 2-2. Students testing their light sensor program.

CHAPTER 3 FINDINGS AND APPLICATIONS

On the pre-course test, ten students indicated that they had a computer at home; one indicated they did not; however the student without a computer at home had no problems with the activity. All eleven indicated that they "like playing with LEGOs."

The pre- and post-course tests had a series of seven questions that were the same. Table 3-1 illustrates the change in responses to these questions from the pre-test to the post-test. The questions were rated on a scale of 1 (strongly disagree) to 5 (strongly agree).

Table 3-1. Responses to Common Questions on the Pre- and Post-Test for Years 1 & 2

Question	Pre-Test Response		Post-Test Response		Percent Change	
	YR1	YR2	YR1	YR2	YR1	YR2
I like math	3.8	3.7	4	4.6	+5	+24
I like science	4.6	4.5	4.5	4.5	-2	0
I can program a LEGO Mindstorm Robot	2.7	2.7	4.2	4.1	+55	+52
I know what a transportation engineer does	3.1	3.0	4.4	3.9	+41	+30
I understand what traffic congestion is	3.2	3.1	4.6	4.0	+43	+29
I will consider going to college and becoming an engineer	4.2	4.0	4.3	4.5	+2	+12
I will study hard at math and science	4.5	4.4	4.3	4.6	-4	+4

The post-course test contained additional questions that were specific to the workshop curriculum as indicated in Table 3-2.

Table 3-2. Responses to Additional Questions on the Post-Test

Question	Response	
	YR1	YR2
Learning to program the robot by thinking logically will help me solve other problems	4.2	3.9
The Lego Mindstorm Robot is easy to use	3.8	3.8
The course helped me understand the use of math, science, and technology	4.2	3.7
Learning about a transportation engineer was interesting	4.2	3.8
I had enough time to complete the exercises	4.3	3.6
The LEGO robotics lessons were hard	2.5	2.0
The LEGO robotics lessons were fun	4.6	4.3
I would like to take another robotics course	4.3	4.2

The post-course test also asked a series of open-ended questions. Responses are indicated below each question.

- What I will remember the most about this Introduction to Transportation Engineering course is:
  - How hard it is to change programs and codes
  - How to program a robot
  - That I love programming
  - That it makes me want to be an engineer
  - How amazing working with a robot can be
  - Most fun programming
  - How to use the sensors
- What is an engineer?
  - A person who solves practical problems
  - A person who used STEM to figure out real world problems
  - A person who helps the community usually with technology
  - A person who designs and builds stuff
  - A person who creates and builds things
  - A person who works with technology

  - A person who uses ways to make life better for people

- What would you like about being a transportation engineer?
  - Making bridges
  - Learning about the robots
  - The ability to work with robots as a tester
  - You can make things cooler than cool
  - Helping people get around easier
- What would you NOT like about being a transportation engineer?
  - Long hours of coding
  - Everything is not fun
  - Testing the robots
  - How much pressure is put on you
  - The hard programming

Responses on the pre- and post-tests show that the participants felt that they had gained a better understanding of the subject matter – especially in terms of programming a LEGO Mindstorm robot (55% increase in YR 1 and 52% increase in Year 2). Even though responses like "I like science" and "I will study hard at math and science" saw a small or no change, the statement "The course helped me understand the use of math, science, and technology" received a 4.2 in YR1 and a 3.7 in YR2 on a scale of 1 to 5 (see Table 3-2) indicating that the participants understood the relationship of STEM to what they were learning about the mitigation of traffic congestion. Participant responses to open-ended questions in the classroom between lessons ("Provide an example of how an intelligent school bus can reduce roadway congestion." "How can an ultrasonic sensor prevent congestion?), and responses from the pre- and post-tests indicated that the students had met the course objectives. The CCMMS AIG teacher confirmed that he had conversations with the students after each session, and they were excited about what they had learned about traffic congestion and related how the robots provided examples of dealing with traffic congestion. Most of the students said they had fun, learned a lot, and

expressed their appreciation that we had come to their school to do the workshop. Several of them asked if we would come back again.

CHAPTER 4 CONCLUSIONS, RECOMMENDATIONS, AND SUGGESTED RESEARCH

CONCLUSIONS

Looking at responses to open-ended questions during the sessions as well as post-test responses indicated that students left the workshop with an understanding of what an engineer does and more specifically the kind of work done by a transportation engineer. Examples provided during the overview session, videos of intelligent vehicle systems, and the software component gave the students an understanding of how crucial STEM is to transportation engineering as expressed through question and answer periods throughout the sessions. The students gained insight as to how traffic congestion impacts their lives and how transportation engineers solve problems in which they can relate. They were able to provide examples of congestion they had seen and asked questions about the educational requirements and work performed by transportation engineers.

During the activities requiring the use of the robot vehicles, they used teamwork and problem solving skills to correct errors when their programs did not run as expected.

Based on observations of the staff presenting the lesson plans and confirmed by conversations the CCMMS AIG teacher had with the students after each session, the LEGO Robot Vehicle lesson plans proved to be an effective way to introduce middle school participants to transportation engineering and increase STEM awareness.

RECOMMENDATIONS

The condensed version of the workshop worked well again. The sessions were long enough for the students to gain an understanding of what they were being taught, but not so long that they lost interest. Having a transportation engineer present the initial overview generated a lot of relevant questions from the students regarding education, STEM disciplines, and work experience. There was a definite advantage in using the robot vehicles to make the lessons fun.

REFERENCES

1. Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook, 2012-13 Edition*, Civil Engineers, on the Internet at http://www.bls.gov/ooh/architecture-and-engineering/civil-engineers.htm. Accessed May 2012.