Upper Cumberland Rural STEM Initiative (UCRSI) STEMmobile: a sustainable model for K-12 outreach

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Abstract

The UCRSI STEMmobile, hosted at 20 elementary and middle schools by more than 75 teachers and 20 principals working with 6900 students in grades K – 8 during the 2013/2014 academic year, is a robust and sustainable model for STEM education outreach especially in rural regions. The 53' tractor-trailer mobile unit with self-contained power via a diesel generator, a heating and cooling system, satellite uplink, and workstations can accommodate twenty-four to thirty students at a time. The unit is stocked with STEM educational equipment specially selected for grades K-8. The STEMmobile has no scientist or engineer on board responsible for instructional delivery; rather, teams of two to four teachers and a principal or designated school leader host the unit at a school location for one week. An initial six-hour professional development workshop is supported through videos and training guides posted on-line in a web-portal, ucrsi.org. The activities on the STEMmobile use the Legacy Cycle project-based learning method. Pre and post assessment data reveals a 30% increase in correct student response on Tennessee standards-based questions.

Keywords

K-12, STEM, Legacy Cycle, outreach, rural

Introduction

STEM (Science, Technology, Engineering and Math) education is one of the newest education initiatives in the country. It is a way of thinking and learning that is meant to keep students on the cutting-edge of the scientific and engineering processes and embedded technology and math skills, and, according to the findings from the IESD 2012 National Survey on STEM Education, 48.7% of the schools surveyed currently integrate STEM into one or more programs, and 30.7% planned on integrating STEM into their curriculum in the next 1-3 years[1].

One of the main objectives of the educational programs is to increase interest in the STEM disciplines, as well as produce graduates with STEM degrees, which are needed more than ever in the workforce. The Department of Commerce notes STEM fields careers are also some of the best-paying and have the greatest potential for job growth in the early 21st century. Their reports also note that STEM workers play a key role in the sustained growth and stability of the U.S. economy, and training in STEM fields generally results in higher wages, whether or not they work in a STEM field[2].

In Tennessee, STEM was given a special priority in the Race to the Top education initiative, introduced by President Obama in 2009, and targeted amounts of resources were allocated, for the first time ever, for STEM education in Tennessee[3]. Using these funds, the Tennessee STEM

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Innovation Network (TSIN) was established, and began creating a system of STEM hubs in cities and regions across the state from which they coordinate efforts to bring STEM education to all of the schools in Tennessee. One of these regional hubs is located in Cookeville, Tennessee at the Millard Oakley STEM Center at Tennessee Tech University; this hub is responsible for a mobile STEM education lab known as the STEMmobile, as one of eight regional objectives for the UCRSI Hub project.

The STEMmobile was designed as a mobile STEM education lab for grades K-8, and has spent time traveling to many schools and counties in the Upper Cumberland areas in order to increase STEM awareness and interest in Tennessee's youth by providing them with hands-on STEM-based activities powered by the Legacy Cycle. This is a relevant and important task in STEM education, as according to the 2012 National STEM Report, 46.5% of the schools surveyed reported that STEM Education in K-8 is lacking or inadequate, and that 48.4% of the schools surveyed stated that the funding designated for STEM education is insufficient[1].

The Oakley STEM Center at Tennessee Tech University is acting on a vision of becoming a national leader in rural STEM education with the mission of supporting innovative teaching and dynamic learning in science, technology, engineering, and mathematics. In 2010, the Center staff took on a challenge from then campus President, Dr. Robert Bell, to create a mobile version of the Center to reach schools, teachers, and students, who may be unable to attend the newly opened facility at TTU. Three years in the making, the response to the challenge required taking a concept for sustained and significant outreach from the conference table to the road, resulting in the STEMmobile.

The STEMmobile, by design, is a unit that has no scientist or engineer on board responsible for instructional delivery. Rather, a team of two to four teachers and a principal host the unit at their school location for one week. An initial six-hour professional development workshop is supported through videos and training guides posted on-line in a web-portal, ucrsi.org. The routing of this unit to 20 elementary and middle schools covered 7500 square miles of the rural Upper Cumberland. More than 75 teachers and 20 principals hosted 6939 students in grades K – 8 in the STEMmobile during November 2013 – May 2014.

The activities on the STEMmobile use the Legacy Cycle project-based learning method. Pre and post assessment data reveals a 30% increase in correct student response on TN standards-based questions. The research behind the Legacy Cycle and the instructional materials provided for teachers to prepare for delivery of instructional lessons in grades 2 – 8 while on-board the STEMmobile will be presented along with the assessment data.

Design, Build and Operation

The Oakley STEMmobile was funded for it's first year of operation 2013/2014 through the Upper Cumberland Rural STEM Initiative Hub Project, a part of the TN STEM Innovation Network (TSIN), grant funds administered by Battelle Memorial Institute under contract to the TN Department of Education with TN First to the Top federal funding. With funding for only one year of deployment, it was imperative to build a detailed understanding of the weekly, monthly, and annual costs associated with running a unit for multiple years. The lessons observed from an operational point of view, including scheduling, weather, training, and

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retraining, daily support and questions from teachers in the field inform the ongoing deployment of the unit and helps inform future funding sources as to the sustainability of the project over multiple years.

The STEMmobile as a mobile learning laboratory was designed, specified, competitively bid, and contracted for build in 2012/2013. It is housed in a 53' tractor-trailer with self-contained power via a diesel generator. The STEMmobile has its own heating and cooling system, a satellite uplink for internet connectivity, and workstations to accommodate twenty-four to thirty students at a time. This classroom on wheels is stocked with STEM educational equipment and includes learning materials and supplies for activities for grade levels K- 8. The Oakley STEM Center also has a lending library of STEM instructional materials to partially equip the STEMmobile, and classroom kits for STEM subjects are already on board, ready to go. The STEMmobile is shown in Figure 1.

Figure 1. UCRSI STEMmobile at Oakley STEM Center showing typical deployment

Funding for the project came from a partnership with TTU, a Tennessee State Legislative Earmark, a grant from Cummins Inc., and finally, a portion of the money that had been allocated to the UCRSI. This money, totaling to approximately $450,000, was used to produce a full-size, 53-foot trailer, furnished as a mobile STEM lab for students that was coined as the STEMmobile.

The STEMmobile is furnished with six large stainless steel lab/work stations, six large flat screen televisions above each workstation, a classroom set of iPads that were designed to connect with the televisions via Apple TVs in order to display teacher presentations or student work via the iPad on any or all of the televisions. The STEMmobile was also fitted with satellite

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internet capability, allowing for increased versatility and function. The space inside the STEMmobile allows for approximately 24-30 students and 1-2 teacher/facilitators.

Operation Costs

The sustainable, continuation funding model for the STEMmobile is based on a break-even structure, where all associated costs to deploy the unit are considered either as annual, monthly, or per site usage costs based on the data we collected in Year 1 of the operation. These costs are then distributed onto a one-week charge. TTU has approved a usage fee of $2000 for the unit to be used on site at a location within a 50-mile radius of the main campus. An adjusted fee for transportation costs beyond this range can be applied for sites located outside of the 50-mile radius from TTU. Additional weeks at a single site location are $1300/week.

Planning conversations with K-12 public school teachers and local education agencies (LEAs) leadership, such as principals, supervisors of instruction, and directors of schools, were held and continue to be held to address concerns about the cost of bringing such a unit to a school for one week of use. The goal was to hold the cost of access to the unit to approximately $5 per child for the experiential learning opportunity to be affordable for a typical classroom or grade level of classes at a school. Comparatively, if teachers were to take a group of 100 students to a science museum for a 3-hour visit allowing for 1.5 hours of driving time both to and from the location, there would be admission fees and busing/transportation costs to consider which could easily reach $15 - $20 per child. The feedback we have received to date is that the $2000/week charge is considered reasonable and achievable for schools to plan for and to develop local sponsorship from community patrons, such as individual community leaders and/or local business and industry support.

Staffing a Mobile Lab – Thinking outside the box

By design, the Oakley STEMmobile is a unit that has no scientist or engineer on board for instructional delivery. A host team of at least two teachers and a principal host the unit on site at their school location for one to two weeks. A close look at the professional development structure to prepare teachers, including their concerns, reveals a model for operation that challenges the comfort zone of all partners. However, it is in the challenge zone that we learn what works and why. Each hosting school site had unique plans and resulting implementations of how to use the unit and a sampling of the data collected has been analyzed for learning gains.

Seventy-five teachers attended a professional development day, 6-hrs duration, as the initial exposure to the STEMmobile to learn how to operate the unit while on site and to experience the learning activities that they would be leading with their students. At the same time, they became members of the UCRSI.org virtual learning community. The initial PD day was supported through subsequent videos, and training guides posted on-line in the web-portal, ucrsi.org and via YouTube. Supportive email strategies and a commitment to be responsive to all concerns raised by the hosting teachers ensured the successful deployment of the unit in the first year.

Table 1 shows the final listing of sites from Year 1 of operation. The UCRSI project worked with more than 75 teachers and 20 principals to support the interaction of 6939 students, grades K – 8, in the months of November 2013 – May 2014.

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Table 1. The STEMmobile 2013/2014 Route Locations and Number of students served

County	Date	School Name	# students
White	11/4 – 11/8, 2013	White County Middle School	313
Pickett	11/11 – 11/15, 2013	Pickett County K – 8	332
Fentress	11/18 – 11/22, 2013	Allardt Elementary	387
Overton	12/2 – 12/6, 2013	Livingston Middle School	432
Jackson	12/9 – 12/13, 2013	Gainesboro Elementary	660
DeKalb	1/13 – 1/17, 2014	DeKalb West Elementary	390
Legislative Plaza	1/21, 2014		
Cannon	1/27 – 1/31, 2014	Woodbury Grammar	48
Wilson	2/3 – 2/7, 2014	Southside Elementary	375
Lebanon Special	2/10 – 2/14, 2014	Walter J. Baird Middle School	700
Sumner	2/17 – 2/21, 2014	Joe Shafer Middle School	200
Trousdale	2/24 – 2/28, 2014	Jim Satterfield Middle School	275
Macon	3/3 – 3/7, 2014	Macon County Junior High	25
Smith	3/10 – 3/14, 2014	Smith County Middle School	72
Cumberland	3/17 – 3/21, 2014	Frank P. Brown Elementary	493
Sequatchie	3/24 – 3/28, 2014	Sequatchie Middle School	670
Bledsoe	3/31 – 4/4, 2014	Bledsoe County Middle School	302
Grundy	April 7 – April 11	Coalmont Elementary	262
Warren	April 14 - May 2	Eastside Elementary	600
Van Buren	May 5 - May 12	Spencer Elementary	153
Clay	May 12 - May 21	Celina K-8, Clay Co	250
		TOTAL	**6939**

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Instructional Resources – Legacy Cycle

The STEM learning activities on the STEMmobile employ a Legacy Cycle approach. These instructional strategies for integrated STEM education learning are meant for use either on-board in the unit, or on-ground in the classroom. The mobile unit was equipped for use by teachers with learning goals they helped establish around the three themes of Water, Energy, and My Food-My body- My Health. The research behind the Legacy Cycle, the instructional materials and the supports provided for teachers to prepare for the instructional lessons in grades 2 – 8 are available on the ucrsi.org site.

The Legacy Cycle is a problem-based learning method based on the educational research presented in the book How People Learn. With roots in science and engineering, it is a student-centered program that allows students to collaborate and find answers to their problems using real-world strategies and research techniques in order to find the best solution for the problem or task that is given to them[4]. It provides students the opportunities to develop skills that are valuable and needed by their future employers, which include communication and collaboration skills, research, problem solving, and critical thinking skills. Students develop these skills through a six stage process: 1) The Challenge, 2) Generating Ideas, 3) Gathering Multiple Perspectives, 4) Research and Revise, 5) Test Your Mettle, and 6) Go Public.

Figure 1. Six stages of the Legacy Cycle

The Challenge: In this step of the Legacy Cycle, students are presented with a problem or situation that requires a solution. These types of problems are not simple yes or no questions, but require deeper knowledge and understanding of the subjects and context information to come to valid conclusions and produce a unique solution[5]. A challenge also sets the stage for the type of

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role the student will engage in, be it a biologist, an engineer, architect, mathematician, chemist, historian, or any combination of these and more.

Generate Ideas: Immediately following the challenge presentation, students are starting to think on their own or with others about how this problem might be solved. Brainstorming, the students can come up with their own creative solutions or steps toward a solution that can be used in the later stages of the lesson. This point can also be used as a formative assessment for the students, with the instructor digging through the knowledge banks each student has about the subject, and gauging the amount of time the students might need for the future steps of the Cycle and difficulties the students may encounter when they investigate further.

Gather Multiple Perspectives: This is where students begin their research to solve the challenge. Using the Internet, books, personal interviews, or other scholarly sources that the instructor deems appropriate, students can gather information about their topic from other experts in the appropriate fields of study. This is important, because real-world scientists and engineers always consult the experts and previous work that has been done before moving forward with their own designs.

Research and Revise: During this stage, students begin to compare their previous ideas and approaches to what they have found with the experts and previous work of others. This will give the students opportunities to discover if their initial ideas were effective or similar to the experts, where they need work, and how they need to improve their original design for solving the challenge. Opportunities for more research about the subject and approaches to dealing with the challenge are also incorporated into this step, as students will need more information to improve and revise their initial designs after comparing them to what they found when gathering perspectives from experts in the field.

Test Your Mettle: After revising their methods, students will then go to the testing stage of their solution. This can be done through performing actual experiments, virtual experiments or labs, using a computer program that is available to test such a solution, or even consulting an expert on the subject about the solution and getting their professional opinion. During this stage, it might become apparent that the student's solution may need revision; in this case, the student will simply return to the research and revise step of the Legacy Cycle to tweak and improve their design. It is important to note that this is a process that real-world scientists and engineers perform in order to perfect their designs, so revising and starting again does not mean failure.

Go Public! Once a satisfactory solution has been obtained, the students must now present their findings. This can be done in written paper, an oral presentation, or even some type of video production. Students can use their skills in differing disciplines in order to come up with a creative and professional manner in which to present their findings to their peers.

Overall, curriculum designed around the Legacy Cycle framework encourage students to draw from the deeper levels of knowledge by presenting them with challenges and letting them solve these problems through inquiry, investigation, and experimentation[5]. This type of advanced constructivist approach helps students develop their critical thinking and problem solving skills, as well as advance their concept and content knowledge about the topic of study, which is a need that any type of curriculum in the 21st century must address as well in order to gain access to funding or adhere to federal and state regulations[2,6,7].

Both teachers and students have had positive experiences with the Legacy Cycle in STEM education, with teachers gaining knowledge and insight into the learning processes of real-life engineers and scientists to use in the classroom, and students making gains in applications of the scientific method, research, and other science skills[8,9,10].

Curriculum for the STEMmobile was designed for grades K-8, with specific modules developed for each grade level. Each module followed the Legacy Cycle model of learning, was aligned to state standards, incorporated the use of educational technologies, and allowed for all students to participate in hands-on activities that led to the solving of a challenge and a display of what was learned and accomplished all in the amount of time that a normal class period would consume. All materials for each unit of study were provided in surplus quantities aboard the STEMmobile, ensuring a user-friendly and pick-up and go environment. Apps developed for the iPads allowed students to flow through the activities and lessons at their own pace, with minimal explicit instruction, which is a core part of Legacy Cycle activities. The topics for each grade level are as follows: 2nd Grade- Magnetics; 3rd Grade- Wind and Air Resistance; 4th Grade- Biochemistry (Vitamin C); 5th Grade- Anatomy and Physiology; 6th Grade- Electricity and Circuits; 7th Grade- Simple Machines; 8th Grade- Electromagnets.

The approximate time that any one class spent in the STEMmobile performing the *Research and Revise* stage of a Legacy Cycle lesson amounted to approximately 45 minutes.

Assessments and Results

Pre and post assessments were developed by Center staff to be used by teachers while hosting the unit at their school; the data was shared with the STEM Center for evaluation purposes within the grant funding for 2013/2104. The pre/post assessment instruments were used with each group of students who interacted with the STEMmobile. Teachers administered the instrument and Oakley STEM Center staff analyzed the data. Sample results are shown for the grades 6 - 8 learning activities. For the purposes of this paper, the matched pair results for approximately 1000 6th, 7th, and 8th grade students are shown in Table 2. Matched pairs were possible when student names were included in the instrument, noting these pairings represent a subset of the total collected data. 978 actual matched pairs were available with 469, 312, and 197 in 6th, 7th, and 8th grades, respectively. The 6th grade assessment instrument had 8 items, the 7th grade had 12 items, and the 8th grade had 8 items. The total number of items marked correct on an instrument is reported as an average across the whole grade level. The Average Improvement Percentage (AIP) is the difference in the pre/post averages. The AIP is 30%, 33%, and 38% for 6th, 7th, and 8th grade respectively. Figure 3 shows a sample pre/post assessment of one-classroom results for matched pairs. The histogram data for this 6th grade class reveals a visually compelling version of the data, showing the numbers of students marking items correctly on the instrument as pre and post with a significant shift in distribution from 2-4 items being marked correctly by a majority of the students to 6-8 items being marked correctly by a majority of students. Figures 4, 5, and 6, show the total set pre and post bar charts for grades 6, 7, and 8, respectively, indicating the 30% shift in number of correct answers on the assessments.

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Table 2. STEMmobile assessment data for 2013/2014

Total number of Matched Pairs	**469**		**Total Possible Points**
6th Grade Average Pretest	3.77	47%	8
6th Grade Average Posttest	6.17	77%	
AIP - Avergage Improvement Percentage	30%		
Total number of Matched Pairs	**312**		
7th Grade Average Pretest	6.74	56%	12
7th Grade Average Posttesst	10.66	89%	
AIP	33%		
Total number of Matched Pairs	**197**		
8th Grade Average Pretest	3.54	44%	8
8th Grade Average Posttest	6.55	82%	
AIP	38%		
Total number of Matched Pairs (6th, 7th and 8th)		**978**	

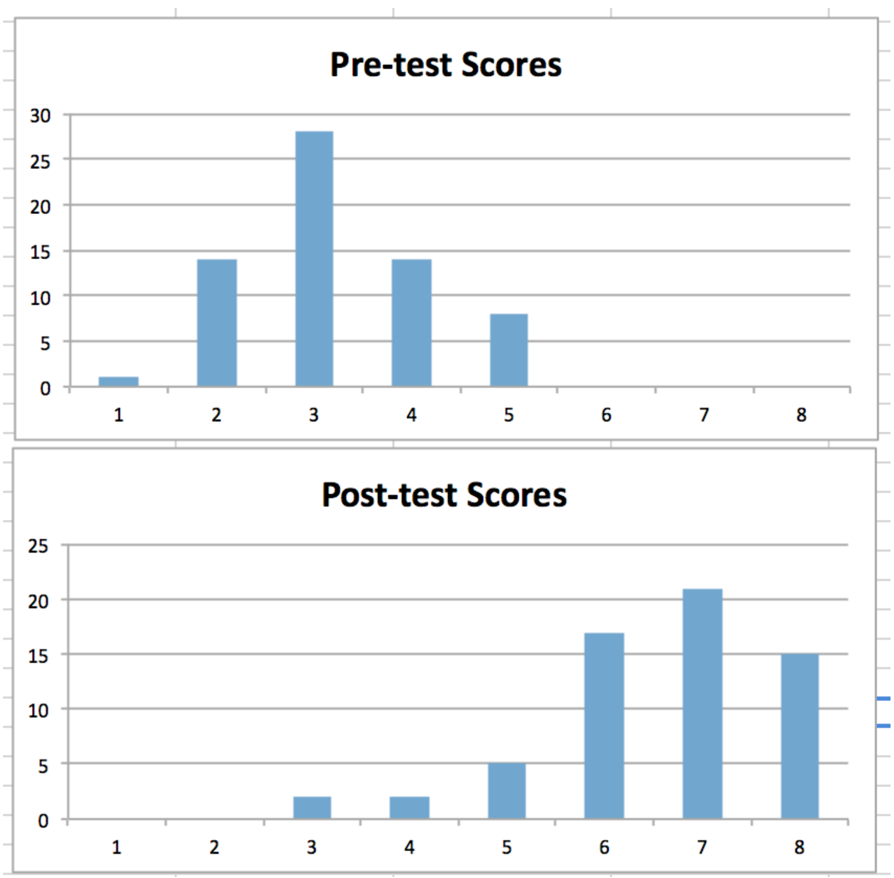

Figure 3. Histograms for one classroom set of 6th grade pre and post assessments

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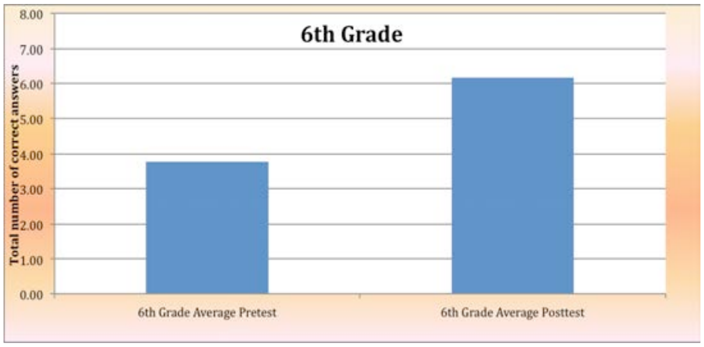

Figure 4. Pre and Post Assessment for 6th grade

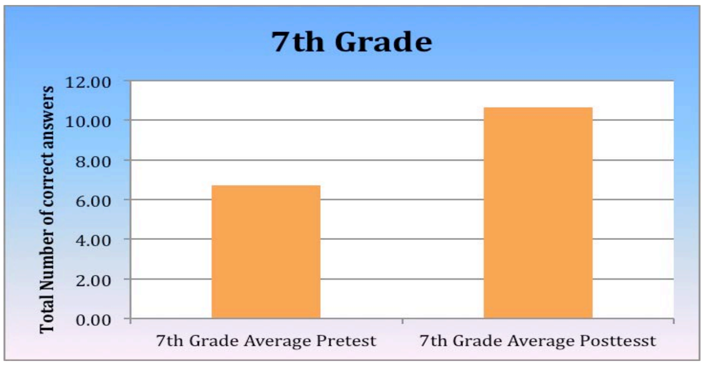

Figure 5. Pre and Post Assessment for 7th grade

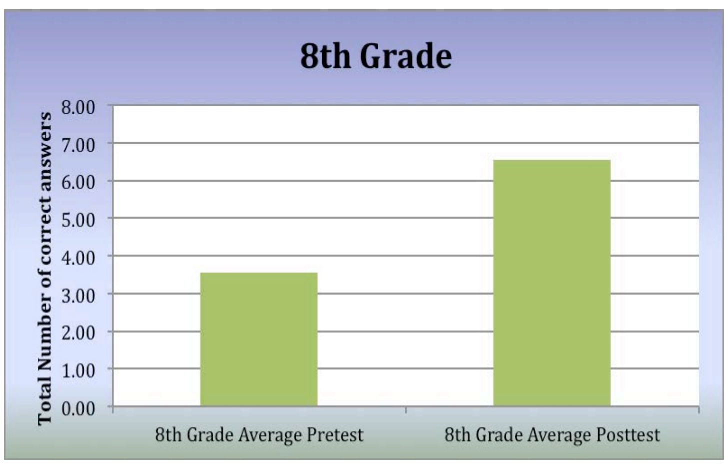

Figure 6. Pre and Post Assessment for 8th grade

Conclusions and Future Work

The STEMmobile Year 1 operation and preliminary data analysis suggests that students exposed to the content aboard the STEMmobile experience significant learning in a short amount of time when participating in Legacy Cycle designed curricula. This type of conclusion is consistent with

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other STEM education studies in which the students participating in small or large scale research projects have made gains in scientific inquiry skills, research skills, and critical thinking skills, which all can lead to increased achievement in math and the sciences[11]. This is especially relevant and important information when the students examined are students in rural Tennessee, due to the focus of Tennessee's STEM education efforts it aimed at increasing achievement and STEM interest in its rural areas[3]. The funds allocated to STEM from the Race to the Top initiative in Tennessee are demonstrated as being effectively applied with the STEMmobile project in the Upper Cumberland Rural STEM Initiative Hub. This project has provided STEM education opportunities to those who might otherwise not have access to these types of instructional resources and methods of integrated STEM learning.

STEM education continues to be a national focus for effort, and is fast becoming a vital part of the future generation's skill sets in order to continue to build a successful America. Previous research and literature indicate that both students and teachers participating in STEM-based research, which includes Legacy Cycle learning, can reap large benefits. In order to help usher in this next set of educational curriculum and teaching methods, it is imperative to offer additional implementations of the Legacy Cycle in STEM education settings. Such implementations need to be introduced and rigorously studied in order to obtain optimal methods of instruction for teaching students the science, technology, engineering and math skills they need to succeed in a 21st Century America. The Oakley STEMmobile provides a sustainable, replicable model that delivers much-needed resources and a means to introduce teachers to methods for STEM integrated instruction working with rural schools across a large geographic region. Furthermore, the STEMmobile provides a platform for research with partner school districts to observe the effects of these new instructional approaches with elementary and middle school students.

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