STEM MODULES: DEVELOPING INNOVATIVE APPROACHES TO ENHANCE STUDENT LEARNING

E. Andrews[1], A. Bufford[3], D. Banks[1], A. Curry[1], and M. Curry[2,3]

[1]School of Education
[2]Department of Chemistry
[3]Department of Materials Science and Engineering
Tuskegee University

currym@mytu.tuskegee.edu

ABSTRACT

In order to increase the pool of students pursuing science degrees at higher educational levels, it is imperative that we expose students to high quality STEM education at early stages. Hence, it is critical that higher-ed and secondary systems partner to develop science materials that will transcend the traditional barriers (access to proper materials, restricted time periods, science equipment, etc.) that are limiting STEM learning within the early learning settings. To that end, through a NSF funded Math and Science Partnership grant, which provides funding for creating partnership among various Alabama schools and universities, we have developed several hands-on STEM modules that use various innovative approaches to expose students to various science concepts. To measure student learning, a pre-test and post-test were given before and after implementation of the STEM Module, respectively, within the middle school classroom. Data collected before and after implementation of the modules revealed that students' knowledge of STEM concepts dramatically improved after implementation of the STEM module activities. In addition, a "student-friendly survey" was given at the end of each module session to measure the clarity and impact of all module activities on students' perception towards module learning.

INTRODUCTION

Given the increasing pandemonium of high-tech technology and human interactions, tasks ranging from managing computer-based applications for medical diagnostic comparisons to the evaluation of environmental claims will require a community that is knowledgeable in the science, technology, engineering, and math (STEM) areas. Furthermore, in order to continue the growth of an U.S. innovative economy, people that have a fundamental knowledge-base in STEM fields will be in high demand to fill many of the positions in our innovation-driven industries.[1] In fact, reports have started to link STEM education as the main cause for the steady decline in U.S. science innovations.[2-4] Furthermore, based on our current educational system's lagging in the production of an adequate workforce with the necessary skills to match the demands of current "high-tech jobs" and pool of students interested in pursuing careers in STEM related areas, the downward spiral of our U.S. innovation-economy will continue.

With greater than 75 percent of all jobs in the U.S. involving either engineering or information technology related tasks, we must revisit how we see STEM in our U.S. school systems. Many studies show overwhelmingly that K-12 STEM learning in the U.S. lags significantly behind the highest performing nations (e.g., China) and that students' knowledge and interest in the STEM subjects have fallen drastically behind the explosive growth of science innovation.[5] In addition it is believed that the attrition point for STEM learning in the U.S. begins with our middle school students. For example, the National Assessment of Educational Progress reported that in 2013 over 70 percent of 8^{th} graders were not proficient in mathematics upon their completion of the 8^{th} grade curriculum.[6] To that end, the partnering of higher education with U.S. school systems to tackle the middle school "woes" in STEM learning is eminent. Thus, in this project we investigate the development of STEM Modules to address the

learning attritions in STEM education and to improve the way at which Middle School Students precieve STEM related careers.

MODULE DEVELOPMENT

The STEM Modules are teacher-made educational units that are developed using the 5-E (i.e., explore, engage, explain, elaborate, evaluate) teaching model.[7] Modules contain a series of activities that address STEM concepts that are listed under the Alabama Course of Study as topics that will be taught in a middle school classroom within the Alabama Black Belt Region. The Black Belt region of Alabama is considered to be the most economically depressed area with very low academic (or STEM) testing performances. In addition, the modules contain supplemental instructional materials that aid middle school teachers in understanding module concepts and best practices on module implementation into their classrooms. For assessment purposes, modules contain teacher reviewed and approved pretests, posttests, and surveys that measure the students learning growth before and after implementation of the module activities and their attitudes towards module style learning, respectively. All modules are evaluated by prospective middle school teachers for clarity, grade-level appropriateness, and suitability for use in the middle school classroom setting.

MODULE IMPLEMENTATION INTO MIDDLE SCHOOL CLASSROOMS

Classrooms are selected based on existing interactions through a National Science Foundation funded Math and Science Partnership (NSF-MSP) grant which serve schools from the Alabama Black Belt Region. Typical class sizes range from 18 to 20 students. Each module contains activities that are used in place of the general classroom text book adopted by the school system to cover STEM concepts focused on in the Middle School Curricula. The implementation process consist of a NSF-MSP related teacher requesting the use of the MSP

modules (e.g., Storm Chasers), and the assistance of the module developer, if necessary to teach concepts on weather instead of using the traditional system-wide adopted science text book. Upon module implementation, a pretest is given to students to measure their knowledge on the subject before implementation of the module and to measure the effectiveness of the module instruction after implementation. No lecture on the Module activities is given to the middle school students prior to the implementation of the STEM module. Students are given a posttest at the end of the module lesson to measure knowledge gains, and a student-friendly survey is given to measure students' attitude towards module learning. In addition, each module session is videotaped to add another dimension for evaluation of the module effectiveness towards student learning.

MODULE IMPACT: LEARNING GAINS AND ATTITUDES

In this report, modules developed on the 5-E model entitled "Space Detectives: What's in the Shining Star" (i.e., Space Detectives) and "Storm Chasers" were implemented into the middle school classroom in place of the traditional text book to cover certain STEM topics. Figures 1(a-c) show results for the pretest and posttest for "Storm Chasers" that were used to assess the module effectiveness and to measure student learning gains on the STEM topic covered. In this instance, the module covered the topic on "how tornados form." At mere glance, it can be observed that after implementation of the Storm Chasers module, student learning gains are significantly improved when comparing the before and after results. In the Storm Chasers module, pretest questions (1-2 and 4-6) show an average learning gain greater than 17% (see Figure 1b). However, nor a positive or negative gain was observed for question number 3. Question 3 addresses the issue of the components of a thunderstorm. In this case, this question can be used as a control since each student has encountered the components of a

thunderstorm through natural storm occurrences. The mere fact that students answered this question correctly on the pretest and posttest validates the notion that the module had no adverse effects on the students' response to Questions 1-2 and 4-6. Question 3 is the only question that received a 100% correct mark on the pretest and posttest. A clearer picture of learning gains can be seen in Figure 1c. The average score for the pretest is 65%. After implementation of the module activities, the posttest scores increased to 91%. Thus a maximum average learning gain for this particular module is observed to be around 26%. Similar trends were observed for the Space Detectives module (data not shown).

The module impact on student attitudes towards module style learning and their assessment of their learning gains can be observed in the survey questions shown in Figures 2(a-d). To eliminate any adverse attitudes towards module style learning and to access the students' attitudes toward the model activities "structure", each student was asked during the survey session if the module instructions on each activity were clear and concise and if activities were fun and keep their interest (see Figures 2a and 2b). 100% of the students attending the module lesson agreed that the lesson was presented in a clear and concise manner and all activities contain in the module were fun and interesting. Furthermore, the students were accessed on module effectiveness through their understanding of the lecture and their confident in explaining the STEM topic to another student (see Figures 2c and 2d). From Figures 2c-d we can conclude that 95% of the students that participated in the module lecture understood the STEM topic covered and could explain this topic to other students. However, 5% of the class (1 student) indicated that they were having difficulties in understanding the module presented STEM topics and could not explain the STEM topic to another student based on the module presentation. This 5% could be a result of student inclusion practices that can be observed in typical middle

school classrooms today. That is, school systems do not separate students with learning disabilities from inclusion into the regular classroom setting. However, based on the response in Figure 2b, all students displayed positive attitudes towards the module activities, which could be equated to the possibility of module style learning as a better way of displaying concepts to students with learning disabilities, as well.

CONCLUSIONS

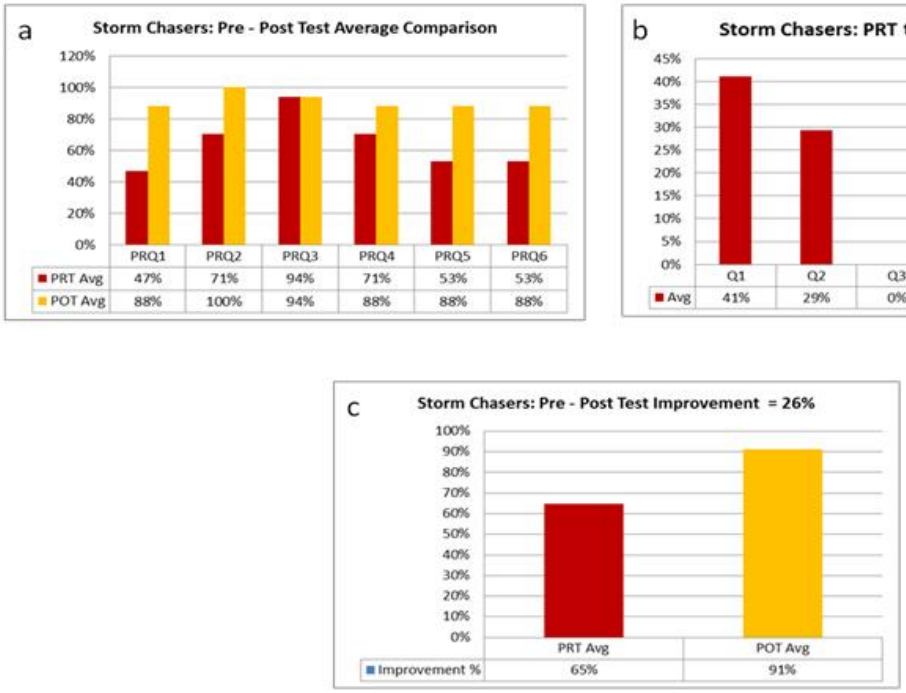
In summary, two STEM modules were developed and implemented into the middle school classroom setting. Each module was equipped with a pretest, posttest, and survey to evaluate students' learning gain and attitude based on module activities. Pretest and posttest responses revealed that students retained significant amounts information upon completion of the STEM modules. Student overall learning gain increased by 26% a measured by the pretest and posttest results. Survey results indicated that students on whole favored the module style learning and could explain the lesson to other students after the module presentation. In addition, it can be concluded that based on the pretest, posttest, and survey responses that students learning gains increased tremendously with module style learning as indicated by the higher percentage scores when comparing the pretest and posttest results.

ACKNOWLEDGMENTS

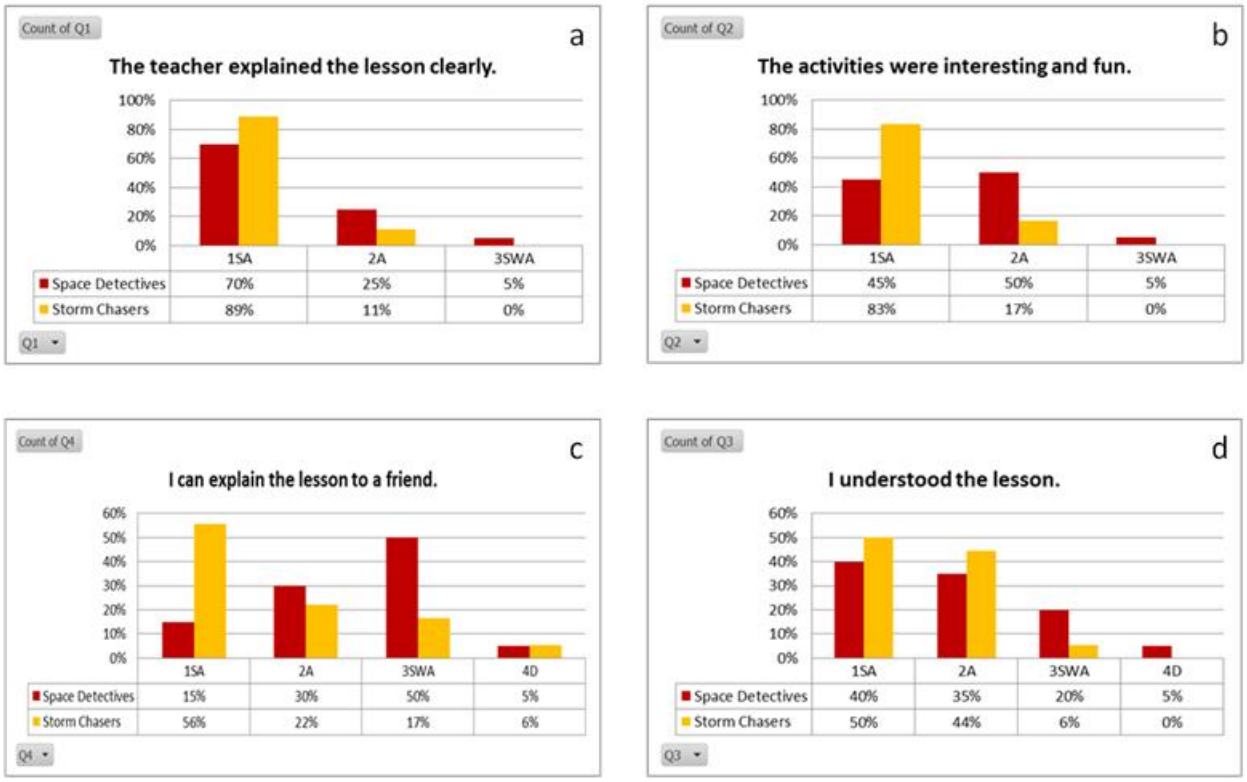
The authors would like to acknowledge support of this work from the National Science Foundation funded under the Math and Science Partnership Program.

References

1. Enrico Moretti, "The New Geography of Jobs", *Journal of Applied Research* **9**, 1-16, (2012).
2. Jeffrey J. Kuenzi, Science, Technology, Engineering, and Mathematics (STEM) Education: Background, Federal Policy, and Legislative Action" *CRS Report for Congress (2008).*
3. National Science Foundation. "Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology*"* Washington, D.C. National Science Foundation (1996).
4. James Fairweather, "Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education" A Status Report for The National Academies National Research Council Board of Science Education (BOSE, Washington, DC, 2010).
5. Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., and Brenwald, S. "Highlights from TIMSS 2007: Mathematics and science achievement of US fourth and eighth-grade students in an international context" (NCES 2009-001 Revised). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education (2008).
6. Schmidt, W.H. (2011). STEM reform: *Which way to go?* Paper presented at the National Research Council Workshop on Successful STEM Education in K-12 Schools. Available at:http://www7.nationalacademies.org/bose/STEM_Schools_Workshop_Paper_Schmidt.pdf.
7. Jim Barufaldi "The 5E Instructional Model of Instruction´Eisenhower Science Collaborative Conference in Austin, Texas, July 2002. Presentation available at: http://www.wisd.org/users/0001/docs/GVC/5E%20Model.pdf



Figures 1(a-c). Comparison of pretest and posttest responses for the Storm Chasers module.



Figures 2(a-d). Survey question responses for the Storm Chasers module.