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Curriculum

Science Alive!: Connecting with Elementary Students through Science Exploration †

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A novel program called Science Alive! was developed by undergraduate faculty members, K–12 school teachers, and undergraduate students to enrich science, technology, engineering, and mathematics (STEM) literacy at community schools located near the university. The ultimate goal of the program is to bolster the scientific knowledge and appreciation of local area students and community members and serve as a model for similar programs. Through the program, we observed that elementary school students made gains toward learning their grade-level science curricula after a hands-on learning experience and had fun doing these hands-on activities. Through the program, undergraduate students, working with graduate students and alumni, build scientific learning modules using explanatory handouts and creative activities as classroom exercises. This helps better integrate scientific education through a collaborative, hands-on learning program. Results showed that elementary school students made the highest learning gains in their performance on higher-level questions related to both forces and matter as a result of the hands-on learning modules. Additionally, college students enjoyed the hands-on activities, would consider volunteering their time at such future events, and saw the service learning program as a benefit to their professional development through community building and discipline-specific service. The science modules were developed according to grade-level curricular standards and can be used year after year to teach or explain a scientific topic to elementary school students via a hands-on learning approach.

INTRODUCTION

It is increasingly recognized that there exists a crisis in science, technology, engineering and mathematics (STEM) education at all levels of the educational system, and especially the K–12 level (6, 7, 10, 14). In Florida, due to ongoing budget cutbacks over the past ten years, several Broward County public elementary schools lost access to science education specialists. In addition, many elementary schools have largely ended the weekly science special program, causing children to become increasingly less familiar with basic scientific concepts through hands-on exploration in the classroom and a greater reliance on standardized workbooks. The role of the science specialists was to deliver 40 minutes of dedicated science education on a weekly basis (www.browardschools.com). The projected effects of loss of specialized STEM education at the grade-school level is a decline in science literacy, resulting in lower performance by students at higher grade levels and less appreciation of science by the public at large. As such, the loss of these educational specialists serves to exacerbate the growing decline in STEM literacy at both the local and global levels (16). To alleviate this decline, many universities across the country are partnering with local community schools to incorporate "service learning" to offer hands-on components to enrich science education (2–4, 9, 17). Some of the programs include University of Alabama's programs (http://research.ua.edu/2009/10/beyond-campus-borders-educators-engineers-reach-to-middle-high-schoolers/); Yale's programs: Demos: Making Science Fun (www.yale.edu/demos/) and Yale Science Diplomats (http://yalesciencediplomats.wix.com/main); and MIT's Lincoln Laboratory Community Outreach (www.ll.mit.edu/outreach/index.html). In Florida, programs include University of Tampa's Microbiology Outreach (www.ut.edu/Bio-Majors-Head-Back-to-High-School.aspx), the Scripps Research Institute's CELLebrate Science with Scripps Florida! (www.scripps.edu/florida/education/community/CELLebrate.html), and University of Miami's Science Made Sensible (https://umsms.wikispaces.com/Home).

Nova Southeastern University (NSU) faculty members (ESL and AR) have been developing one such program called Science Alive! (12). Here we describe how, through Science Alive!, NSU faculty members and students reached out to

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†Supplemental materials available at http://asmscience.org/jmbe

their own community schools. We present two schools with which the program has worked: Welleby Elementary School (WES) and Manatee Bay Elementary (MBE) School. Through this project, NSU faculty and students were trained as aids to the teachers in an effort to strengthen STEM literacy and provide college-age role models for the elementary students (8, 11). Modules (Appendices 1 and 2) are used to present a scientific topic to elementary school students via a hands-on learning approach. The modules can be replicated and used year after year. Materials used are simple, everyday household items that can be easily purchased from the local supermarket.

This project allows undergraduate students to work directly with their faculty in their local communities. Students and faculty are able to create a novel program or unique modules within a program and see it through its implementation stage. Students not only implement an existing program, but creatively utilize material they have learned in their classes to design activities and deliver them to a varied audience. Through this program, undergraduate students have more opportunities in the field of science (13), learn how to present basic science content using simple experimentation to young students, and become better public speakers. The science modules presented here have been designed by NSU undergraduate students and overseen by faculty members.

Intended audience

The program is targeted toward students in the K–12 grades to provide the students an opportunity to be involved in hands-on science activities. In this paper, we report on modules specifically field-tested with groups of second-grade students. Undergraduate students who are majors in biology, chemistry, allied health, science education and nonscience disciplines use these prepared modules to lead hands-on science exploration in the local elementary schools. As these students finish their programs, they stay involved in Science Alive!, providing opportunities for current undergraduate students to interact with graduate students and alumni who are professionals in STEM fields.

Prerequisite student knowledge

Before participating in the hands-on Science Alive! activities, the elementary school students have reviewed the topics with their classroom teacher using the standard state-approved science workbook. This introduces them to the basic scientific concepts and associated skills, such as the ability to identify what a force is and an understanding of the states of matter. Students are also introduced to the steps of the scientific method, wherein they learn that one of the first steps is to form a hypothesis. However, they have not applied their knowledge in an experimental setting by implementing the scientific method on their own. The Science Alive! modules presented here help to make the scientific concepts clearer and personally memorable for the elementary school students. Appendix 3 notes how the Science Alive! modules tie to Florida's state science standards. Typical student answers for each survey question and how they would be scored are provided in Appendix 4.

Undergraduate students with a basic background in the sciences (high school level) should be able to use the modules as a guide for instruction. Prior to our outreach events, undergraduate students read the modules and then attend a one-hour practice session where they perform the module activities and get comfortable with presenting the materials. The faculty member, team leaders (explained below), and other experienced volunteers clarify any questions, and/or unfamiliarity. Additional science training has not been required for any science event conducted. For all grade levels that the Science Alive! program has worked with, the indicated timeline and preparation time have worked well with our undergraduate students regardless of their major.

Learning time

The time required to conduct the activities in each science module is approximately 30 minutes, including explanations and instructions to the elementary students, demonstrating the activity, and then allowing the school students to perform the activity themselves. The modules are designed such that one topic can be delivered in a 45-minute session at the local school for a classroom of 20 participating children.

A few days prior to the event, undergraduate students meet with the faculty member leading the event for about an hour to review the paperwork, become familiar with the materials and activities, print instruction documents, etc. If the undergraduate students are unfamiliar with the topic, the faculty member and other more experienced volunteers help practice the activities with the new undergraduate volunteers.

Around the same time, the faculty member e-mails the pre-event survey to the grade school classroom teacher (or brings printed copies to the teacher), who administers the pre-event survey to the class and will bring the completed surveys to the event. The grade school students complete the post-event survey after the event, preferably on the same day. The grade school teacher returns the surveys to the faculty member shortly thereafter. The assessment surveys (both the pre- and post-event student surveys) will take approximately 10 minutes each to complete. These assessments and the Science Alive! programs were determined to be exempt from full review by the Institutional Review Board at Nova Southeastern University.

Learning objectives

Participating in a community outreach program such as Science Alive! is of great benefit to elementary school students and undergraduate students. In this report, we focus on the learning objectives for the elementary school

students. Both modules included basic scientific knowledge questions and activity-specific questions related to the hands-on activities in the modules.

I. Upon completion of the Forces, Motion, and Energy Module activities, elementary school students will be able to:

   1. Give an example of energy and a force (General scientific knowledge)
   2. Understand that magnets can be pushed or pulled by other magnets (Activity-specific knowledge)
   3. Predict what will happen in various experimental settings, specifically (Activity-specific knowledge):
      a. What will happen when a ping-pong ball is placed in the air stream of a hair dryer
      b. What will happen when one end of a straw is cut into a point and you blow into it
      c. What will happen when you rub a balloon on a fuzzy blanket and place it near gelatin powder

II. Upon completion of the Matter Module activities, elementary school students will be able to:

   1. Name three different states of matter (General scientific knowledge)
   2. Give an example of a solid, a liquid, and a gas (General scientific knowledge)
   3. Predict what will happen in various experimental settings, specifically (Activity-specific knowledge):
      a. What will happen when Borax is combined with glue
      b. What will happen when dry ice comes into contact with a soapy solution
      c. What will happen when cornstarch is mixed with water

Assessment data obtained are provided in Appendix 5 (Figs. 1a–c and 3a–c for the Forces, Motion, and Energy Day objectives; Figs. 2a–c and 4a–c for Matter Day). The benefits of this type of program for the undergraduate students have been addressed separately (5). We also provide informal assessments garnered from undergraduate students and teachers at the elementary schools that suggest added positive outcomes of the Science Alive! program.

PROCEDURE

Two modules (Forces Day and Matter Day) were built and used in elementary schools (second-grade level). Below are the materials used in the activity, instructions for students, instructions for faculty, surveys used to determine student learning, sample data, and safety issues to keep in mind.

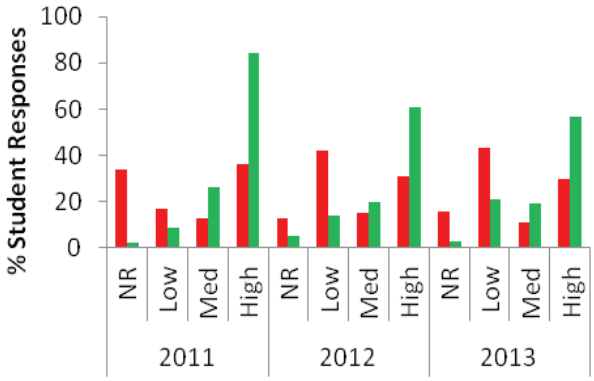

FIGURE 1. (replicate of Fig. 1a in Appendix 5). Summary data for all survey questions relating to the Forces Day Module activities and learning outcomes. The percentage of student responses (for all survey questions) that were no response (NR), low, medium, and high quality answers for pre-event (red) and post-event (green) questions given as part of Forces Day at Welleby Elementary School for the years 2011, 2012, and 2013. The NR answers decreased post-event in all years, suggesting greater confidence in answering, and the high-quality answers increased significantly.

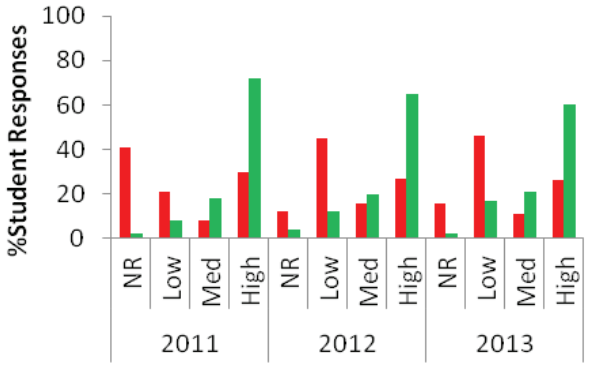

FIGURE 2. (replicate of Fig. 1c in Appendix 5). Summary data for four program-specific survey questions: learning outcomes 2 (understand that magnets can be pushed or pulled by other magnets) and 3 (being able to predict what will happen in various experimental settings specifically related to forces) for forces, motion and energy. NR = no response. Pre-event answers are red; post-event answers are green.

Materials

The materials used for the different activities are listed in Appendices 1 and 2. Materials listed are for conducting the activity one time with one group. The activity can be repeated for however many groups will be involved. We had groups of approximately 20 elementary students participating in Science Alive! activities for 30 to 45 minutes back-to-back on one day until all of the second-grade classes had the opportunity to visit the science lab. The materials for each activity, which can all be procured at local grocery and/or department stores, are set up at individual tables in the school classroom or event room. Each activity table has around seven to ten grade school students and two or three undergraduate student volunteers.

Student instructions

Instructions for elementary students are explained to them verbally. Instructions for adult activity leaders (undergraduate students, grade school teachers who may choose to do these activities again at a later date, or parents from a science night event wishing to replicate these activities in their home with their children) are provided in writing (Appendices 1 and 2). The handouts for current activities are also posted on the elementary school websites (http://wellebyelementary.org/apps/pages/index.jsp?uREC_ID=267340&type=d&termREC_ID=&pREC_ID=508597).

On the day of the event, the students and faculty members arrive at the grade school 30 minutes prior to the event to set up the activity stations. The stations are set up either in the grade school classroom or in a common location such as the school media center or available empty classrooms. For a single-themed event (such as Forces Day or Matter Day), four or five individual stations are set up. The event is conducted with grade school students rotating through the stations in small groups (typically 4–5 students at a time). The event begins with the faculty member introducing the undergraduate student volunteers to the K–12 classroom and providing a short 10-minute introduction of the main topic that will be presented as an activity to the students. The faculty member then hands over the classroom to the undergraduate student volunteers, who, in small groups with a peer-leader, begin explaining the concept of the activity using the handouts as a guide (Appendices 1 and 2). The undergraduate students encourage the elementary school students to think about the activity as an experiment using the "scientific method" and prompt students to develop a hypothesis for the different activities being conducted. Following that, they begin to perform the procedures step by step so that the students at the table can follow along and perform the activities themselves with the guidance of the volunteers. The volunteers get ready to redo the activity for the new round of grade school students as all the students in the class rotate through. The undergraduate students help clean up the premises.

Faculty instructions

Conducting science activities at local schools involves coordination on several levels. The overall approach for the Science Alive! program is as follows. The faculty member first identifies an interested local school that is in need or would appreciate a hands-on science learning activity. The faculty makes contact with a teacher or the administration at their local school (it started with schools where a faculty member is a stakeholder such as being the parent of a student at the school, or schools close to or affiliated with our university). The faculty member discusses with the teacher how the Science Alive! team member can assist the teachers in different grades, an agreement is made, and dates are set for the activity. To build the Science Alive! team, e-mails are sent to students of various student groups on campus, or the project is announced in faculty members' classrooms. In Broward County, FL, anyone requesting to work/volunteer in public schools must register through the local county website and be screened prior to approval (a five- to seven-day process). The approval is valid for one academic year.

Following registration, students are notified by professors via e-mail of upcoming Science Alive! events, and volunteers are selected as needed. Students can sign up via Google Forms or by sending e-mails to faculty indicating their interest and availability. The faculty member develops the details of the event in collaboration with the community school. Materials are procured from local grocery stores by the faculty member, the teacher at the grade school, or the school PTA.

Suggestions for determining student learning

To determine whether the elementary students are making learning gains, we conducted pre-event and post-event surveys. Elementary school student assessment surveys are provided in Appendices 1 and 2. Undergraduate students participating in the event and the grade school teachers were also surveyed at the end of the event to determine the value of the event to their professional development (Appendix 6).

Sample data

Data figures (1–4) are provided in Appendix 5 showing learning gains for both the Forces and Matter Day Modules at Welleby Elementary School (WES) and Manatee Bay Elementary School (MBE). Two of these figures showing learning gains for the Forces Day Module at WES and two showing learning gains at MBE for Matter Day are included in the discussion section below.

DISCUSSION

The Science Alive! program has been run in local elementary schools in Broward County, FL, since 2009. Approximately 14 schools have participated in the program. Science Alive! modules have been presented in various levels of K–12 classrooms. Different modules have also been presented as an afterschool activity or a science night involving students and their families. Science Alive! events have served some 7,000 people to date, in single classrooms (20 students), entire grade levels (75–100 students), or an entire institution (about 500 people at a single event). The program has been served by about 500 volunteers who have contributed 2,500 volunteer hours throughout the program's history.

Appendix 4 presents details on the scoring of responses to pre- and post-event surveys, with examples of actual answers. For future events, a numeric rubric is being designed

to aid in the scoring of responses. Several people, including the student team leaders and the faculty mentors, score the responses. The team leaders and the faculty member review all responses and reach a consensus on the scoring. Select participants (who provided consent) were interviewed and recorded on video (Appendix 7). Data from these interviews were not used for video response assessment; however, a rubric for video interviews could be developed as an additional assessment measure.

The responses from the pre- and post-event surveys were scored as low, medium, high, or no response (NR). Questions that had a minimal response, indicating poor understanding of the material, are scored as "low." A "medium" response is one where the answer to the question is partially answered or improper words are used in the answer, indicating partial understanding of the material. The "high" score is used when the question is completely answered with the appropriate scientific language, indicating a full grasp of the concepts. We further broke down the survey questions as entire-event questions (which included all survey questions), general scientific knowledge survey questions relating to the specific topic (forces or matter, for example), and activity-specific questions directly linked to the individual activities conducted (Appendix 4).

Evidence of student learning

The learning objectives of being able to give an example of energy and a force, understanding that magnets can be pushed or pulled by other magnets, and being able to predict what will happen in various experimental settings related to forces, motion, and energy were achieved as a result of the second-grade students' exposure to the hands-on activities described (Figs. 1a–c and 3a–c in Appendix 5). Results indicate that a greater percentage of students post-participation in the hands-on event tend to respond to questions asked on the surveys rather than leaving them blank (NR on the figures); fewer than 10% of students left questions blank post-event compared with 30 to 40% of students leaving blanks on the survey questions before the Forces Day event. Following the event, their confidence in answering the questions rises.

Results from questions related to all learning outcomes for the Forces module (Fig. 1; Fig. 1a in Appendix 5) indicate that the percentage of students' responses increases following a hands-on activity. For the general scientific knowledge questions (Figs. 1b, 3b in Appendix 5), a greater percentage of students attain complete comprehension (high, in green) after the hands-on activity. These general knowledge questions refer to the learning outcome "give an example of forces and energy," and includes questions 1 and 2 from the forces survey (Appendix 1: Pre and Post Survey). In addition, after the hands-on activities, a greater percentage of students comprehend activity-specific information (Fig. 2; Figs. 1c, 3c in Appendix 5) directly linked to learning outcomes 2 and 3. After the event, students were able to understand that magnets can be pushed or pulled by other magnets and were better able to predict what will happen in various experimental settings related to forces, motion and energy, including questions 3 to 6 from the forces survey (Appendix 1: Pre and Post Survey).

Similarly, with the Matter Day Module, the learning objectives of being able to name three different states of matter and give an example of a solid, a liquid, and a gas, as well as being able to predict what will happen in various experimental settings, were achieved as a result of the second-grade students' exposure to the hands-on activities described (Figs. 2a–c, 4a–c in Appendix 5). Results indicate that a greater percentage of students post-participation in the hands-on event tend to respond to questions asked on the surveys rather than leaving them blank (NR on the figures); fewer than 10% of students left questions blank post-event compared with 20 to 25% before the Matter Day event. Following the event, their confidence in answering the questions rises.

Results from questions related to all learning outcomes for the Matter Day Module (Fig. 3; Fig. 4a in Appendix 5) indicate that the percentage of students' responses increases following a hands-on activity. For the general scientific knowledge questions (Figs. 2b, 4b in Appendix 5), there is a greater percentage of students attaining complete comprehension (high, in green) after the hands-on activity. These general knowledge questions refer to the learning outcome "name three different states of matter" and "give an example of a solid, a liquid, and a gas," and include questions 1 to 4 from the matter survey (Appendix 2: Pre and Post Survey). In addition, after the hands-on activities, a greater percentage of students comprehend activity-specific information (Fig. 4; Fig. 4c in Appendix 5) directly linked to learning outcome 3. After the event, students were better able to predict what will happen in various experimental settings related to matter, including questions 5 to 7 from the matter survey (Appendix 2: Pre and Post Survey).

Benefits to additional audiences

In addition to elementary school students, the program is of benefit to other groups such as the undergraduate students and the grade school teachers. Undergraduate students have indicated that participating in the events has been of great benefit to them. Informal assessments indicate that over 96% of students intend to continue to be part of the program. A majority of the students indicate that they "strongly agree" that the program is of benefit to them, allowing them to learn their own subject material better, communicate more effectively with peers and others, work as a team with a larger group of people, get involved in community service, and interact with fellow students (Appendices 6 and 7). This program serves to engage our students and many share with us that participating in Science Alive! has been a highlight of their educational experience. In fact, one NSU Science Alive! student participant used material

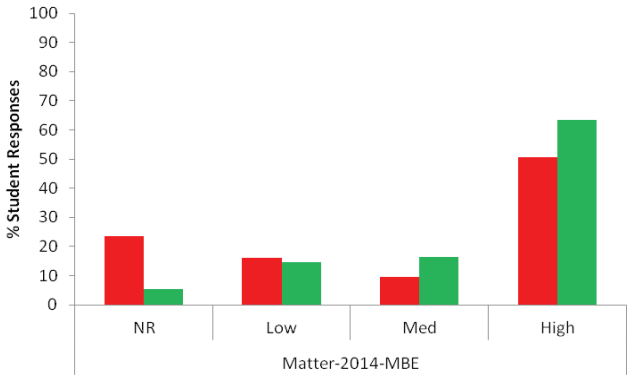

FIGURE 3. (replicate of Fig. 4a in Appendix 5). Summary data for all survey questions relating to the Matter Day Module activities and learning outcomes. Percentage of student responses (for all survey questions) that were no response (NR), low, medium, and high quality answers for pre-event (red) and post-event (green) questions given as part of Matter Day at Manatee Bay Elementary School (MBE) for the year 2014. A decrease in NR responses and an increase in high-quality responses indicated learning gains.

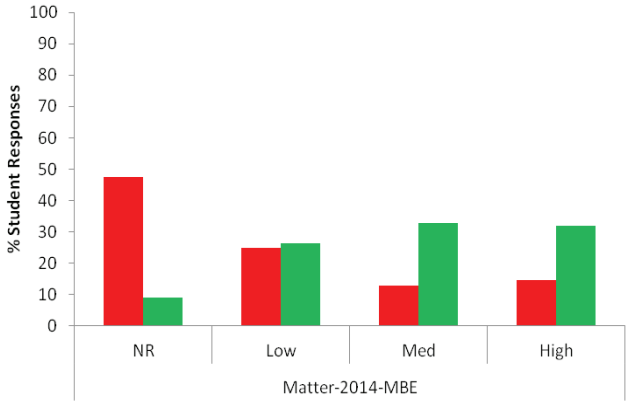

FIGURE 4. (replicate of Fig. 4c in Appendix 5). Summary data for four program-specific survey questions: learning outcome 3 for matter (being able to predict what will happen in various experimental settings specifically related to matter). MBE = Manatee Bay Elementary School; NR = no response. Pre-event responses are red; post-event responses are green.

she had learned and developed through this program to become a Teach for America fellow (2013–2015) in Baltimore, MD (15). Another NSU student participant, following an enriching experience with Science Alive!, became a local area leader for the America Reads/America Counts program (2013–2015) in Broward County elementary schools. One student volunteer is currently teaching elementary students for a program in South Korea.

Science Alive! is of great value to teachers in the grade schools (Appendices 6 and 7). Surveyed teachers have consistently scored "highly agree" for questions addressing the value of such a hands-on program for their students and their interest (as teachers) in the program being included as part of the classroom activity curriculum. The program also serves as a venue to enable professional development for school teachers and administrators. For example, two teachers at Welleby Elementary School developed a poster describing the Science Alive! Family Night (2012) at their school for the Central Organization Rising Educators (CORE) Broward County's graduation ceremony. The Superintendent of Broward County Schools, school board members, district personnel, and many principals, assistant principals, teachers, and school-based personnel throughout the district attended this event. The Science Alive! event at WES has also been featured in Broward County's Central Area Newsletter, *Bits and Pieces* (1). Teachers and students from Manatee Bay Elementary partnered with the Science Alive! team to build Florida native gardens and planted local crops as part of their Florida Agriculture in the Classroom program.

In addition to being presented as grade-level themed activities at the school, Science Alive! has also been conducted as a family event at local schools, where families and children come in to attend these events, with the undergraduate students leading the activities. The program has also been run as a mentoring event as part of afterschool programs at a local school and library.

Possible modifications

Science Alive! has continued to develop over the years since its initial offerings. The program has been expanded to include more elementary schools in Broward County and has also been expanded to include middle and high schools (not presented in this paper). From the beginning of this program, all stakeholders worked very well together, and the needs of the students were well understood. Thus, not too many changes have been made to the program over the years. However, we did realize that it was important for university faculty to collaborate with elementary school classroom teachers. To achieve this, we started each year by engaging in discussions with classroom teachers to gauge what topics were of most interest to them so that we could plan our science activities around concepts that were most significant to the classroom. We have worked with classroom teachers and noticed that when the classroom teachers provided more assistance with teaching the relevant concepts, students were able to make even greater learning gains. Also, it was important to keep the costs of the materials down to a realistic amount. Initially, we had post surveys for each activity within the module. However, that was found to be too time consuming so the surveys were restricted to a simple one-page form covering one large topic being discussed.

The program could be further modified to be part of a regularly offered service learning course. Science Alive! at NSU has been conducted as a service learning course in both the Biology I and Biology II for majors courses (5). In both of these courses with a service learning component, students worked in groups of two or three to develop new

hands-on learning modules and presented these modules to their classmates. In some cases, these modules were incorporated into the themed activities (i.e., light-saber training for Forces Day).

SUPPLEMENTAL MATERIALS

Appendix 1: Forces Day Module activities and handouts
Appendix 2: Matter Day Module activities and handouts
Appendix 3: List of hands-on science activities developed and tied to Florida State Science Standards
Appendix 4: Table of sample pre and post survey responses
Appendix 5: Data figures
Appendix 6: Surveys of teachers/college students
Appendix 7: Video interviews and other resources

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