Strengthening STEM Education through Community Partnerships

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Abstract

California State University San Marcos (CSUSM) and San Marcos Elementary Schools have established a partnership to offer a large-scale community service learning opportunity to enrich science curriculum for K-5 students. It provides an opportunity for science, technology, engineering, and math (STEM) majors to give back to the community, allowing them to experience teaching in an elementary classroom setting, in schools that lack the resources and science instructor specialization needed to instill consistent science curricula. CSUSM responded to this need for more STEM education by mobilizing its large STEM student body to design hands-on, interactive science lessons based on Next Generation Science Standards (NGSS). Since 2012, the program has reached out to over four thousand K-5 students, and assessment data have indicated an increase in STEM academic performance and interest.

Introduction

School districts across the state of California (CA) are failing to teach the scientific disciplines (Dorph et al. 2011; Rumberger 1985). More specifically, when elementary students receive science instruction, it is often of poor quality and in fleeting instances (Conderman and Sheldon Woods 2008). Only one in ten CA elementary students receives interactive and engaging science instruction on a regular basis (Schweingruber et al. 2007). The lack of instruction in science content is evident at all grade levels, but is perhaps most clearly apparent and detrimental in K-5 education (Rumberger 1985).

Due in part to the long history of the No Child Left Behind Act (NCLB) and the newly and widely adopted Common Core State Standards (CCSS), CA elementary students have received a disproportionate amount of their educational focus on mathematics and language arts (Cody 2013; Kelly 2000; Luehmann 2007; Windschitl 2002), resulting in minimal exposure to the sciences
because they are not tested until the fifth grade (http://star.cde.ca.gov/star2012/AboutSTAR.aspx). As a result, students’ levels of investigative inquiry are not evaluated or stimulated until the late stages of elementary education. Due to such late testing, the early teaching of science material is regarded as unimportant and not pertinent to students’ “success” as elementary students, and this results in a lack of science instruction that fails to spark STEM interest levels among K-5 students (Avard 2009; Chubb and Chubb 2012; Goodrum et al. 2012; Goodrum et al. 2001; Herranen et al. 2015).

CA districts currently focus primarily on the core disciplines of English Language Arts (ELA) and Mathematics, where state funding is most heavily allocated, inferred from the focus of the Common Core State Standards. Districts adhering to the older NCLB increased instructional time by 43% for ELA and Math at the expense of STEM content, since conventional core disciplines such ELA and Math are regarded as crucial skills for the early academic development of elementary students. However, when considering early science education as a tool to promote critical thinking and analytic skills (Bailin 2002), it is distressing that the sciences are not also accepted as a core discipline. As a response to the lack of science in the classroom, children become isolated from the scientific process and even intimidated by the subjects, creating a pattern that denies them insight into investigative thinking and problem solving. These formative years are crucial not only for providing students opportunities to get excited about STEM content, but also to prepare them for later years of intense science exposure in their education. Furthermore, early exposure to science may set more students on a STEM-specific professional path for later life (Lyon et al. 2012; Tai et al. 2006).

Lack of professional development and teacher interest in science instruction is also a problem in elementary school education (Abell and Roth 1992; Epstein and Miller 2011; Tilgner 1990). With consistent exposure to ineffective and ill-prepared classroom instructors, students suffer in science and mathematics when compared to students who work with highly trained teachers (Abell and Roth 1992; California Council on Science and Technology 2010; Tilgner 1990). Without persistent incorporation of the sciences into school curricula, teachers are not prepared to effectively teach the subjects, and there is a lack of specialized science instructors to fill this gap (Abell and Roth 1992; Avard 2009; California Council on Science and Technology 2010; Herranen et al. 2015; Tilgner 1990).

California has shown a strong commitment to standards-based learning through its adoption of the Common Core State Standards (CCSS), which were largely developed by National Governors Association Center for Best Practices and the Council of Chief State School Officers, incorporating input from K-12 teachers and administrators, state leaders, and education experts (http://www.corestandards.org/about-the-standards/frequently-asked-questions/ and http://www.corestandards.org/assets/CCSSI_K-12_dev-team.pdf)(CCSESA 2013). The main goal of the CCSS is to equip students with the necessary skills in ELA and Mathematics to prepare them for success in a post-high school environment, whether it is post-secondary education or the workforce. However, within the general literacy framework of the CCSS, there are three main concerns from the perspective of early STEM education: the CCSS do not cover investigative and inquiry based science education until the fifth grade; the CCSS are meant to be interpreted at the state and local levels by school administrators; among the 135 members who wrote and reviewed the CCSS, there were no early childhood professionals or K-3 teachers (Miller and Carlsson-Paige 2013). Not providing detailed STEM education and assessment until the fifth grade is detrimental in itself; but there are other aspects of the CCSS that further hinder early STEM education. The CCSS do not call for the training of STEM educators; rather the CCSS prompt teachers and administrators to adapt the CCSS according to their own vision. Granting more flexibility to local levels for decision-making and interpretation of the standards is likely to marginalize STEM education due to the initial lack of resources and specialized instructors allocated for STEM education (California Council on Science and Technology 2010). The sciences are often overlooked or oversimplified as a result of being deemed too difficult or underfunded to implement. This leads administrations to focus more on traditional core disciplines, or to cut corners in science education and teach shallow concepts. With so few professional science educators as part of the development process (Franz and Enochs 1982; Hurd 1970), insufficient facilities and equipment (Tosun 2000), and poor teacher attitudes (Koballa
and Crawley 1985) there is little optimism that a STEM curriculum would receive the attention and championing from administrations that would be required for STEM incorporation into the K-5 curricula.

The Next Generation Science Standards (NGSS)
The National Science Education Standards from the National Research Council (NRC) and “Benchmarks for Science Literacy” from the American Association for the Advancement of Science (AAAS) have historically acted as guidelines for states in the development of state specific science standards, and in this case the CCSS (http://www.nextgenscience.org/frequently-asked-questions#1.1). However, these documents have become obsolete in the last fifteen years as advances in science and effective science pedagogy have been made. Thus, the NRC created a framework with new definitions about what it means to be proficient in science. Experts in the fields of science, engineering, cognitive science, curriculum, assessment, and education policy were involved in the developmental process of this framework that would ultimately be the foundation for the NGSS (http://www.nextgenscience.org/frequently-asked-questions#3.1). The mantra assumed by this framework was that employability in the 21st century would largely depend on skills based in the sciences and mathematics (Langdon et al. 2011; Stine and Matthews 2009). Along with reading, writing, and communication skills, the NGSS recognizes aptitude in science and mathematics as equally important for integration into the workforce. Rather than leaving its standards up for interpretation, the NGSS clearly defines what science concepts ought to be taught, as well as how to establish connections between cross-disciplinary concepts. This is one of the ways in which the CCSS have failed in the past: not only do they fall short in establishing core science instruction, but they make no effort to create relationships between different subdisciplines within the sciences, such as medicine and plant biology. When students can identify and bridge the gaps between two or more science subdisciplines they are able to exercise an improved intrinsic understanding of the concepts involved by seeing how each discipline acts independently in addition to how the disciplines act in tandem.

The move towards the NGSS is very district/school specific, but at a state level CA first started to implement the NGSS system in 2013 in the context of a continuous learning process. The plan consists of installing three main phases (the awareness phase—introduction to the CA NGSS [2013-2015], transition phase—building foundational resources [2015-2018], and the implementation phase—fully aligned curriculum [2016 and beyond]) (California Department of Education 2014). The NGSS were in part developed to reflect the type of job distribution expected for the future. The National Science Foundation “estimates that eighty percent of the jobs created in the next decade will require some form of math and science skills.” Even if students do not pursue a STEM-based career, the benefits of including more STEM content at all education levels include problem solving, independent thinking, and literacy in the workings of the natural world (Brophy et al. 2008; Bybee 2010; Eshach 2003; Katehi et al. 2009; Portsmore and Rogers 2004; Sanders 2009).

Tackling the Lack of Early Science Experiences through Service Learning
In 2011, a small team of CSUSM STEM faculty recognized this dilemma and proposed to conduct a two-week after-school science enrichment program in partnership with Twin Oaks Elementary School (TOES), a local K-5 school in the San Marcos Unified School District (SMUSD). The principal and CSUSM STEM faculty were overwhelmed with the response of more than a hundred parents who gave permission for their children to participate in the after-school science program. The participating children were thoroughly engaged in the pilot program and the parent feedback was supportive, indicating a strong desire to continue with the program in the future.

After realizing the success, there was an immediate desire among the participating CSUSM faculty to install a more substantial and embedded STEM project-based learning outreach program (Goebel et al. 2009; Han et al. 2015; Perkins et al. 2015). STEM project-based learning is an instructional strategy that is student driven, interdisciplinary, collaborative, engaging, and hands-on/technology
based (El Sayary et al. 2015; Han et al. 2015; Larmer et al. 2015; Savery 2015). Capitalizing on the student body within the College of Science and Mathematics, faculty recruited STEM undergraduate majors interested in helping on the project. Teams of CSUSM students were tasked to develop hands-on, experiential science lessons that were based on the Next Generation Science Standards to supplement elementary curricula using the “5E’s Learning Cycle Model”—Engage, Explore, Explain, Elaborate, Evaluate—from the Biological Science Curriculum Study (BSCS) (Bybee et al. 2006). The goal was to create one-hour-long lesson plans that encouraged inquiry-based and hands-on learning to excite these young students with innovative learning experiences (Christensen et al. 2015; Greenspan 2016; Hampden-Thompson and Bennett 2013; Shelton 2016).

In Fall 2012, these first lessons were designed and administered to every K-5 classroom at TOES, reaching over 850 elementary school children and incorporating sixty college students who acted as instructors.

Program Extension

The program eventually evolved into a large-scale community service project, involving the recruitment of 220 STEM majors from across fifteen courses each semester. As a result of the increase in the number of participants, the program expanded in the spring of 2013 to include another local Title 1 elementary school, San Marcos Elementary (SME). At SME, the teaching model adopted was slightly different. Specifically, all fifth grade classes received one hour-long lesson per week for six weeks, with a different NGSS standard addressed each week. This different model was created in order to evaluate student retention of the STEM content taught, using pre- and post-assessments. The TOES program, although without assessments, continued to deliver a lesson to elementary school students at all grade levels each semester.

Methods

Recruitment of CSUSM Science Majors

CSUSM professors offered service learning as an extra credit option in many of the core science curriculum classes that students must take in order to fulfill their science degrees (Table 1). Recruitment from these classes resulted in a large enough student participant pool (180-220 undergraduate students) to cover 40-54 lesson plans a semester.

Lesson Plan Development

In order for CSUSM undergrads to receive the extra credit for their participation, they had to satisfy a number of program requirements in addition to preparing a lesson plan based on assigned elementary standards intertwined with curriculum content covered in their own college-level classes. Students interested in the program were invited to an online module where they selected a K-5 grade to sign up for on a first-come, first-served basis. Depending on the grade level they signed up for, undergrads were assigned a presentation date and group partners who also signed up for the same presentation date. Through the module students gained access to important information and instructions for the program, including the ability to use a discussion board, select times for rehearsal sessions, and review general guidance for the program. Groups consisted of two to three STEM-based undergraduates assigned with an Integrated Credentials Program (ICP 381) student or a CSUSM Noyce Teacher Scholar. The Noyce Scholars is a program that responds to the critical need for K-12 teachers in STEM fields by encouraging talented STEM students and professionals to pursue STEM teaching careers. STEM undergraduates designed engaging experiments and brought forth content knowledge, while ICP and Noyce Scholars contributed a pedagogical perspective by conducting classroom management training and translating science concepts into age-appropriate lesson plan material.

To obtain credit for completing the project, students had to satisfy five main requirements that defined the outreach program rubric. The first was to attend an orientation. The orientation explained the overall purpose and goals of the program and provided detailed explanations of the lesson plan rubric, due dates, and expectations. Here the students had the opportunity to meet the directors of the program and ask specific questions. All the information from the orientation was accessible on the module, with additional discussion forums where students could ask follow-up questions.

The second component of the rubric was designing a lesson plan. Groups were given two weeks to collaborate
on a lesson plan for their selected grade via electronic communication and in-person meetings. They collectively selected their lesson plan topic (while still adhering to the subject matter of their university level class and their respective elementary grade level standards) unless the elementary class requested a specific topic in advance. All the lesson plans were developed from the “5 E’s Learning Cycle Model” (Bybee et al. 2006). This model provided clear delineation of a lesson plan into five main sections: Engagement, Exploration, Explanation, Elaboration, and Evaluation. Each lesson plan began with an “Engagement” activity designed to quickly stimulate student interest while pre-assessing their prior understanding of the subject. Engagement activities capture students’ interest and help them to make connections with what they may already know about the subject. Most engagement activities consisted of short instructor demos, videos, or a classroom activity to swiftly capture student interest. Next was the “Exploration” phase, where students encountered hands-on experiences in which they explored the concept further. They received little explanation and were encouraged to collaborate with peers to define the problem or phenomenon in their own words. The purpose of this stage of the model is for students to acquire a common set of experiences from which they can help one another make sense of the concepts and observations. Students must spend significant time during this stage of the model talking about their experiences, both to articulate their own understanding and to understand other peers’ viewpoints. The “Explanation” section provides the scientific explanations and terms for the topic under investigation. CSUSM students presented the concepts via lecture, demonstration, PowerPoint, or other multimedia. Undergrads were reminded to avoid strict lecturing in this phase and instead encouraged to keep the classroom discussion as interactive as possible. Students then used the terms to describe what they had experienced thus far in the presentation and began to mentally examine how this explanation fit with what they already knew. In the “Elaboration” phase students were given an opportunity to apply the concepts they had learned by conducting an experiment that the undergrads set up. Peer to peer interaction was essential during the “Elaboration” stage. By discussing their ideas with others, students could construct a deeper understanding of the concepts. Crucial to the experiment was a hands-on component where students had a chance to use instrumentation, make observations, record data, and reflect upon

### TABLE 1. Classes that participated in the service learning STEM project.

<table>
<thead>
<tr>
<th>Class</th>
<th>Participating Semester</th>
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<tbody>
<tr>
<td>Animal Physiology (Bio 353)</td>
<td>Fall 2013, Spring 2014, &amp; Fall 2014</td>
</tr>
<tr>
<td>Biochemistry (Chem 341)</td>
<td>Spring 2013 &amp; Fall 2013</td>
</tr>
<tr>
<td>Biotechnology (Bio 355)</td>
<td>Fall 2014</td>
</tr>
<tr>
<td>Evolution (Bio 212)</td>
<td>Spring 2013, Fall 2013, &amp; Fall 2014</td>
</tr>
<tr>
<td>Genetics (Bio 352)</td>
<td>Fall 2013, Spring 2013, &amp; Fall 2014</td>
</tr>
<tr>
<td>General Biology (Bio 210)</td>
<td>Spring 2013 &amp; Fall 2013</td>
</tr>
<tr>
<td>Integrated Credentials (ID 381)</td>
<td>Spring 2014</td>
</tr>
<tr>
<td>Microbiology (Bio 367)</td>
<td>Spring 2013, Fall 2013, Spring 2014, &amp; Fall 2014</td>
</tr>
<tr>
<td>Molecular Cell Seminar (Bio 560)</td>
<td>Spring 2013</td>
</tr>
<tr>
<td>Molecular Cellular Biology (Bio 351)</td>
<td>Spring 2014</td>
</tr>
<tr>
<td>Organic Chemistry II (Chem 202)</td>
<td>Fall 2013 &amp; Spring 2013</td>
</tr>
<tr>
<td>Physics (Phys 380)</td>
<td>Fall 2013 &amp; Spring 2013</td>
</tr>
<tr>
<td>Physics (Phys 202)</td>
<td>Fall 2014</td>
</tr>
<tr>
<td>Protein Structure &amp; Function (Chem 450)</td>
<td>Spring 2013</td>
</tr>
<tr>
<td>Virology (Bio 504)</td>
<td>Spring 2014</td>
</tr>
</tbody>
</table>

Students in the Integrated Credential Program (ICP) are liberal studies students in a combined undergraduate and elementary teacher credential program. There was at least one of these students per group to provide experience in teaching strategies, while the STEM major students provided content.
their findings (Greenspan 2016). Finally, an “Evaluation” section concluded the lesson plan. It was designed to allow the students to continue to elaborate on their understanding through interactive classroom discussion and to evaluate what they knew now and what they had yet to figure out. Evaluation of student understanding should take place throughout all phases of the instructional model; in the “Evaluation” stage, however, the teacher determined the extent to which students had developed a meaningful understanding of the concepts. The last ten minutes of the lesson were dedicated to answering student questions about college. The elementary students had the opportunity to ask the CSUSM students about their experiences, which built a role model relationship.

A template lesson plan was provided on the module for the students to use so that finished lesson plans were all uniform in the 5E model. The requirements for the lesson plans were K-5 standards-based, focused on hands-on experiences and interactive engagement and contained both a data collection component and a take-home component. The goal was to have each lesson plan written in such detail that in the future any elementary school teacher, specifically those with non-STEM backgrounds and little experience teaching STEM content, could comprehend and completely implement the lesson plan from start to finish. Upon completion of a first draft, lesson plans were uploaded to the module, where they were edited and annotated by at least one individual—the graduate student coordinators, CSUSM faculty, or an elementary teacher for feedback and advice. The undergraduates then adapted their lesson plans, based on those recommendations, and resubmitted a final draft, which was again looked at by another member of the committee. Once the lesson plan gained approval, the group attended one or two mock sessions, which could be scheduled through the module, depending on the coordinators opinion of how prepared the group was to present in the classroom. If the lesson plan was not satisfactory, it was sent back for a rewrite along with assistance from one of the program directors. In the end, each lesson plan was approved by the program directors, a CSUSM professor and an elementary teacher. We used the following criteria to approve the lesson plan: were all the components of the 5E lesson plan completed, were the main objective and standards clearly articulated, was it clear what the children as well as the presenters (CSUSM students) would be doing at each stage of the lesson, and what was the take-home message?

The third component of the rubric was to attend a mock session. Here undergrads ran from start to finish through their lesson plan in front of program directors to gain approval on lesson plan items such as their featured experiment, physical materials, worksheets, PowerPoints, and multimedia. Groups demonstrated their experiment or provided a video of the experiment to prove that it was legitimate and well thought out. If the committee decided the group was not ready to present, then they were asked to attend another mock session. Other details such as classroom organization, teaching tips, attire, and etiquette were addressed as well. Any necessary science equipment required for their lesson plan was documented and requested by program directors to be borrowed from various CSUSM departments. Program directors then made the equipment available on the day the undergrads presented at the elementary schools.

The fourth component of the rubric was to present the lesson to their designated classroom. Each group arrived 30 minutes prior to the presentation start time, so that they could collect their equipment and set up the classroom. After completion of their lesson they were responsible for cleaning the classroom.

The fifth component, and to get full credit for the program, undergrads had to fill out a final reflection survey and a peer review evaluation located on the module. The surveys addressed questions about their experience with the elementary students and program administration and their interests in teaching, as well as their desire for future participation in the program.

Pre- and Post-Assessments
The San Marcos Elementary School (SME) model was identical to the TOES model except that only fourth and fifth grade classes were targeted due to the number of participating undergrads available. Fourth and fifth graders were the primary target age range, since fifth grade is the year students are STAR (California Standardized Testing and Reporting) tested in science for the first time. The goal for this SME model would be that the same class of students would receive science instruction for three to six weeks in a row and then be assessed for their retention
of the material with pre- and post-assessments to determine if there were any measurable effects. The evaluation questions were multiple choice questions taken from released California Content Standards Tests as part of the STAR Program. There were twenty questions selected at random for the assessment. The Online Assessment Reporting System (OARS) (http://www.redschoolhouse.com) were used to data-mine and correlate the pre- and post-tests. With OARS, we were able not only to identify specific standards the students improved on; we were also able to predict their possible percentile score on the California exams. All pre- and post-assessments were also analyzed using a paired end t-test with a 0.05 significance as previously established in Fraenkel et al. (1993).

In the first SME semester (Spring 2013 cohort) the evaluations were given to thirty-two students (out of 137 students) who were selected to be a representative cohort of the entire fifth grade population. This cohort consisted of one entire class that received the science instruction who placed together based on previous performance in language and math state assessments in the previous year (STAR testing; http://star.cde.ca.gov/star2012/help_scoreexplainations.aspx). There are four categories of STAR results: Advanced, Proficient, Basic, Far below/Below basic. Eight students in this class fell into each category, yielding the thirty-two students. The next semester (Fall 2013 cohort) every fifth grade class at the school was evaluated with a new set of questions. The pre-test was administered by SME teachers one week before the lessons began during school hours. The post-test for the Spring 2013 semester was administered a week after finishing the six weeks of lesson plans. In the Fall 2013 session, the post-assessment was administered the following semester, a total of four months after completing the lesson plans to see if the students understood the material or just had short-term retention following the lessons.

**Research**

Over the past three years, the CSUSM STEM Program has delivered 125 lesson plans and provided over 4,000

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**FIGURE 1.** Results from the Spring 2013 pre- and post-assessment (n=30). Mean score for the pre-assessment was 6.5 (sd=3.145), and the mean increased to 11.2 (sd=2.389) in the post-assessments.
instances in which students at two neighboring elementary schools engaged in hands-on and experiential learning encounters with science. Lesson plan topics range from chemistry, physics, and engineering to physiology, botany, and many other subdivisions of biology. Hands-on experiments range from dry ice demos, growing yeast balloons, launching bottle rockets, microscopy of viruses, periodic element games, and centripetal force demonstrations to creating plant biomes and countless others. CSUSM undergrads have been able to come up with unique and creative ways to address the California State Standards and NGSS while creating a step-by-step lesson plan so that any non-STEM instructor would be able to confidently and successfully create an engaging hour of science.

In the Spring 2013 cohort, 32 students out of 137 from SME were selected to be a representative cohort of the entire fifth grade student population, as they reflected an equal representation of each of the performance groups in language arts and mathematics. These students completed a 20-question pre-assessment test and then retook the same 20-question test as a post-assessment after their six consecutive weeks of lessons given by CSUSM college students. During this time there was no additional science given to the students in their regular elementary classroom environment. The post-assessments showed an increase in academic STEM performance. On average the students increased their test scores by 4.7 points (t = -8.5925, df = 29, p-value = 1.83e-09; Figure 1) after the completion of CSUSM lesson plans.

For the Spring 2013 model, the Online Assessment Reporting System (OARS) was used. This information was rearranged into Figure 2 showing the results from the pre-assessment and the corresponding post-assessment for that semester. In the pre-assessment, 70% of the students tested in the Far Below Basic category and only 3% tested into the Proficient level (national goal). There were no students who tested into the Advanced level. After just six weeks of science instruction, there was a 33% decrease in the Far Below Basic and a twenty-three percent increase into the Proficient level. There was even a 3% increase into the top Advanced level.

Instead of teaching all the fifth grade classrooms for six weeks, the program was adapted to cover both the fourth grade classrooms and the fifth grade classrooms for three weeks in a row. The idea was that the fourth graders would eventually have two rounds of the program before being assessed in the fifth grade and four rounds before entering middle school. To see the effect of having only three weeks of consecutive lesson plan education,

every fifth grader at SME was evaluated before the start of the lesson plans implementation. Unlike the Spring 2013 cohort, these students took the post-assessment test the following semester to truly demonstrate information retention of the lesson plans education. The results of post-assessments again showed an increase in academic STEM performance. On average the students increased their test scores by 0.96 points ($t = -5.514$, df = 98, p-value = 2.849e-07; Figure 3) after the completion of three weeks of CSUSM lesson plans. Hence, from these two pilot cohorts, six weeks of instruction resulted in a greater increase in performance after the exposure to science lessons, although there was also an increase after only three weeks of instruction.

After only a single but very engaging lesson on elements and the breakdown of the periodic table, there was a huge increase in answering two of the post-assessment questions. An example of these questions was “A student is grouping elements by chemical properties. According to the periodic table, the element with similar chemical properties to carbon (C) and tin (Sn) is a) gold (Au), b) calcium (Ca), c) nitrogen (N), and d) silicon (Si) [Correct answer]. More than half the students who initially answered incorrectly on the pre-test were able to answer it correctly on the post-assessment. Towards the start of that semester the students were exposed to a chemistry lesson on the periodic table trends through the use of an engaging game. This game emphasized periodic trends such that elements near each other on the periodic table share chemical properties. By making this activity into a game, played against their peers, there was an increase in student involvement, leading to an increase in information retention. Such an activity, whether it be an in-class game or an interactive hands-on activity, can transform the process of learning science content into a fun and memorable experience; an experience that leads to an increase in students’ scores from pre- to post-assessment.

The STEM outreach also has a positive impact on CSUSM STEM majors. The overall feedback at the end of the semester was positive from both the elementary students/teachers and the CSUSM undergrad students/

**FIGURE 3.** This graph displays the results from the Fall 2013 pre- and post-assessment (n=99). Mean score for the pre-assessment was 2.323 (sd=1.499), and the mean increased to 3.283 (sd=1.504) in the post-assessments.
faculty. We collected feedback data from the CSUSM participants through a survey presented online. There was an overwhelming positive response to the program in its entirety. Not only were there positive gains in the elementary school test scores but the survey also showed that 87% of CSUSM students proved to have had a rewarding experience. In fact, as a result of their experience, 43% of the CSUSM students actually started considering teaching as a career path. Ninety-seven percent of the students recommended that the program continue, and 80% of the CSUSM students reported they had learned something new that would benefit them in their future career path. Each year the program grows, and as directors we have adapted its design to what works and have accommodated all the new additions. The program was not based on a previous model but was created on the basis of a conversation between an elementary school teacher and a CSUSM professor, indicating the authentic and truly collaborative nature of the work.

Discussion

This large-scale program has successfully developed a model to deliver hands-on science lessons to elementary school children by college STEM majors. The program was implemented as result of the strong partnership between the local elementary principals and CSUSM faculty. This program served two Title I schools in the SMUSD. These schools do not have the resources, including time and expertise, to deliver high-quality, impactful hands-on science instruction. Only six extra hours of engaging hands-on lesson plans implemented by STEM undergrad role models was enough to improve the elementary students’ retention and interest in the subjects.

It’s important to note that most of the assessments and lessons were given prior to the initial release of NGSS and were based on the previous California state standards. As soon as the NGSS were released in CA, however, we immediately began to design our lesson plans to include the NGSS aspects. Our goal was to develop hands-on lessons that would provide meaningful engagement for the children. Coincidentally this is also the emphasis of NGSS. The NGSS science and engineering practices involved asking questions, developing and using models, planning and carrying out investigation, analyzing and interpreting data, constructing explanations, engaging in argument from evidence, and obtaining, evaluating, and communicating information. The DCIs (disciplinary core ideas) were the primary target in the design of the lesson plans since they are as close as the NGSS has come to setting standards, while XCCs (cross-cutting concepts) were used minimally during the lessons. This was primarily because the idea of XCCs had not been fully developed or released at the time of the initial lessons. However, XCCs could well be incorporated into future lessons. Finally, SEPs (Science and Engineering Practices) would involve explaining a concept or phenomenon by using or creating models. This is practically the core to our lessons; all are engaging and hands-on.

Elementary students experienced an overall increase in retention of knowledge and STEM academic performance in all our cohorts. The Spring 2013 cohort had a greater improvement, most likely due to a longer exposure to more lesson plans. However, even in the Fall 2013 cohort, when this time frame was cut in half to three weeks, we were still able to see an increase from the pre- to the post-assessments. This illustrates the dramatic effect on students when they are given hands-on, engaging experiments. These experiments stimulated students’ interest, which led to an increased retention of knowledge of the material, ultimately facilitating a better understanding of the subject matter and content. The Fall 2013 cohort was tested four months later, and the students were still able to retain much of the information from the lessons given by the CSUSM students. There was also a notable increase in the elementary students’ interest levels in STEM fields from the start to the finish of the program. By the end of the program, the students were announcing that science had become their “favorite subject.” This program helped bridge these students from viewing science as an intimidating and hard subject to a familiar and fun enterprise.

From the exit survey for the college students it was reported that the program also increased undergraduate interest in teaching, which was an added benefit of the program (Borgerding 2015; Certificates 2008; Moin et al. 2005; Tomanek and Cummings 2000; Worsham et al. 2014). The survey also showed that this extra credit opportunity benefited the students by improving their
understanding of the college-level course from which they were initially recruited. The college students elaborated that the ability to teach a complex topic that they were studying to students at an elementary level was a true challenge and tested their own understanding of the topic. As a result, the faculty members at CSUSM have had a positive response to continuing to offer this opportunity to their students.

The program has also created a partnership in the San Marcos community, between elementary students and college students. These young elementary school students are repeatedly surrounded with intelligent and successful college-level role models instilling in them the notion of achieving a college degree. The CSUSM undergrads served as role models for the children in multiple ways: clarifying misconceptions about college life, encouraging the importance of attending college, exemplifying proper behavior as a college student, and inspiring them with the notion that college was a feasible achievement (Bruce et al. 1997; Marks et al. 2004; McMinn 2015; Schmidt et al. 2004; Sjaastad 2012; Tierney and Branch 1992). It was verified that the children viewed the college students as role models through verbal cues indicating the children’s new desire to attend college and become a scientist just like their college student instructor. An additional benefit of the program is that the CSUSM student body that participated was reflective of the children in the community. Specifically, CSUSM is a Hispanic Serving Institution with about 34% of students self-reporting as latino/a (https://www.csusm.edu/communications/cougarstats/). These students continue to serve as great models in our community, especially in our project, where the elementary schools served have higher numbers of latino/a students, 64% at Twin Oaks Elementary (Jacobsen 2015–2016) and 95.3 percent at San Marcos Elementary (Wallace 2012–2013). As a result, not only were the CSUSM students experts on the topic but they were of the same ethnicity as the students and were seen as a success story about going to college: the elementary students could see their STEM teachers as role models for themselves.

This partnership could be easily replicated and repeated in other universities, with neighboring local elementary schools. The model has been shown to be effective in raising awareness of and interest in STEM education. The CSUSM program has been contacted by other elementary and middle schools with hopes of expansion to their schools, both inside and outside of the SMUSD. We anticipate the expansion of the project to other elementary schools while still maintaining the SME and TOES models. It would also be beneficial to track the undergraduates who reported an increased interest in teaching after participating in the program to see if they eventually did start to take education classes. We would also like to compile all the lesson plans we have collected and make them readily available for elementary school teachers. We expect to continue assessing our results each semester, to measure improvements in standards-based testing, to identify program areas that need enhancement, and to compile data for future funding and expansion.

Acknowledgements
We would like to thank CSUSM Office of Civic Engagement, Office for Training, Research and Education in the Sciences, and the NOYCE Scholar Program for funding the project. We would also like to acknowledge all the teachers at TOES and SME who participated and supported this program, CSUSM Dean Katherine A. Kantardjieff, and all CSUSM faculty who offered the program in their coursework. Lastly we would like to thank all the CSUSM undergrads who participated.

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