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Evaluating a Science Professional Development for Elementary Teachers: Effects on Self-Efficacy and Perceptions of Classroom Practice

Author
Hankel, Nancy Aurora

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Evaluating a Science Professional Development for Elementary Teachers: Effects on Self-Efficacy and Perceptions of Classroom Practice

A dissertation submitted in partial satisfaction
of the requirements for the degree Doctor of Education

by

Nancy Aurora Hankel

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Abstract of the Dissertation

Evaluating a Science Professional
Development for Elementary Teachers:
Effects on Self-Efficacy and Perceptions
of Classroom Practice

by

Nancy Aurora Hankel
Doctor of Education
University of California, Los Angeles, 2019
Professor Christina A. Christie, Chair

This study was a descriptive, mixed methods evaluation of a science professional development called Engaging Young Minds (EYM), for elementary teachers in Los Angeles. It was developed in response to the implementation of the Next Generation Science Standards (NGSS) and the summer 2016 session focused primarily on the NGSS Practice of Scientific Modeling. Participants included teachers who participated in the summer 2016 session as well as teachers who had participated in prior sessions. A total of 86 teachers completed a pretest-posttest survey during the 2016 session, 26 prior participants completed a single-administration survey, and ten teachers were interviewed at the end of the 2016-2017 school year.

Survey data revealed that teachers reported significant improvements in their confidence following participation in EYM as well as expected changes to their classroom practice following EYM. Additionally, teachers showed significant growth in their understanding of scientific modeling during the summer 2016 session.

Through interviews, teachers revealed that they were more likely to teach science, but their actual classroom practice changed little. The main change reported was in the area of student talk and student-led discussions; namely that this noticeably increased following EYM in 2016. Teachers did not retain as much understanding of scientific modeling as expected and implemented little scientific modeling practices in their classrooms during the 2016-2017 school year.

Findings indicated that the transition to the NGSS in elementary classrooms was more complicated than originally anticipated. Additionally, while EYM was a higher-quality professional development opportunity for teachers, it led to little change in actual classroom practice.

Keywords: Next Generation Science Standards, professional development, elementary science teaching

The dissertation of Nancy A. Hankel is approved.

Louis M. Gomez

Beverly P. Lynch

Kathryn M. Anderson

Christina A. Christie, Chair

University of California, Los Angeles

2019

Dedication

For Ambrose Charles Otieno

"Nobody warned me how much love weighed,

or that happiness could carry me into the sky." - Joan Logghe

&

J.A.K.

one of the best teachers both in and out of the classroom

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Amanda – thank you for helping me through some dark, dark days and encouraging me to finish this thing. Now I can stop bringing over my low-level guilt about not working on my dissertation with me when I come over and you can stop asking me when I'm going to be done!

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Vita

2009	Bachelor of Arts, Psychology Hillsdale College Hillsdale, Michigan
2011	Master of Arts, Organizational Behavior and Evaluation Claremont Graduate University Claremont, California
2011 – 2016	Education Research and Program Evaluation Associate Cobblestone Applied Research & Evaluation, Inc. La Verne, California
2016 – present	Program Evaluation and Outcomes Manager Victor Community Support Services Chico, California & Perris, California

Chapter 1 – Introduction

This project is a descriptive study of a science professional development (PD) program provided to elementary teachers in Los Angeles Unified School District (LAUSD). Ample opportunities exist for teachers to participate in science-related PDs, especially considering the implementation of the new Next Generation Science Standards (NGSS). Unfortunately, PDs tend to be ineffective, one-shot workshops which result in little transfer into teachers' classroom practice or effect on teacher confidence (Sparks & Hirsh, 2000). The PD which is the subject of this study consisted of four days during a summer session and four optional follow-up sessions during the subsequent school year. The content focused on several key areas: teacher science content knowledge (particularly in the physical and nanosciences), teacher confidence and self-efficacy around teaching science, and incorporation of scientific modeling strategies into their science lessons. Modeling in science lessons is an integral part of the new science teaching pedagogy which accompanies the NGSS. The goal is to improve teacher confidence in teaching science through targeted content sessions and provide teachers with tangible modeling strategies to use in their classrooms.

Problem Statement

The introduction of the NGSS has brought a renewed focus on science instruction at the elementary level. Students in elementary grades are underperforming in science (Blank, 2012; U.S. Department of Education, 2000). In addition to scoring below other countries on international measures of science achievement, students fail to demonstrate proficiency on national science achievement measures in the United States (OECD, 2014; US Department of Education, 2015).

In recent years, the science instructional minutes students received have been both low-quality and few. In California specifically, elementary teachers reported spending an average of 1.8 hours per week on science instruction in the 2017-2018 school year, which was the same as the 2007-2008 school year but significantly lower from numbers reported in the 1990s (Blank, 2012; Dorph et al., 2011; Lambert, 2019; U.S. DOE NCES, 2015). There are at least two explanations of the decline in time for science. First, Harlen & Holroyd (1997) found that one way teachers compensate for their incomplete knowledge of science content is to teach as little of it as possible. Second, following the passage of No Child Left Behind, elementary teachers in districts across the country significantly increased the amount of instructional time devoted to Language Arts and Math since those were the subjects in which students would be tested the most. On average, districts decreased science instructional minutes by 76 per week to accommodate for increased time devoted to Language Arts and Math (McMurrer, 2008). Though districts or states may not have mandates regarding content-specific instructional minutes (for example, California does not while Arizona does), teachers have a finite amount of instructional time per day and will choose to spend more time on subjects which will be tested annually and are a focus of educational policy. With the implementation of NGSS, teachers will most likely shift instructional minutes again to accommodate for the increase in science content which will also be tested.

One way to improve both teacher confidence and student performance is to engage teachers in PD. PD can help teachers build their content knowledge and skills to ultimately improve student performance (Harwell, 2003; Mizell, 2010). Evaluating this PD program, including its implementation, will help to determine how it affects teacher science content knowledge, confidence around teaching science, which parts of the PD are most effective and which may not contribute to effective implementation to help improve the PD in the future.

The Next Generation Science Standards.

In California, as is true in states across the country, elementary school teachers are in the process of preparing to teach and implement the NGSS. The NGSS were developed by educators, policymakers, and content experts in twenty-six states. They were officially adopted by the California State Board of Education in September, 2013. The implementation timeline for both the state of California as a whole and LASUD specifically considered 2013-2016 the "awareness phase," 2015-2018 the "transition phase," and 2016 and beyond the "implementation phase" (California Science Teachers Association, 2015). Please see Appendix A for a full description of the original implementation timeline.

The NGSS are based on a framework developed in part by the National Research Council (NRC) of the National Academy of Sciences. There are three dimensions of the standards – Practices, Crosscutting Concepts, and Disciplinary Core Ideas (DCIs). In theory, when students learn and master all three of these dimensions, they will be proficient scientists.

Beginning in kindergarten, the standards incorporate elements of the physical sciences, life sciences, earth and space sciences, and engineering, technology, and the application of science to everyday life. Teachers tend to be more comfortable teaching biological sciences over physical sciences (Harlen & Holroyd, 1997) but all content areas are emphasized equally in the NGSS.

Effective implementation to fidelity of the NGSS necessarily means teachers need training and PD to ensure they understand and know how to teach the new standards. Similar to other districts across the country, LAUSD provides workshops and webinars related to the NGSS and other STEM topics for teachers. However, these one- or two-day opportunities are not enough. Teachers need ongoing, relevant professional development to truly affect their practice.

Scientific modeling in science lessons.

Embedded within the NGSS are eight guiding principles, officially referred to as Science and Engineering Practices (herein referred to as Practices). The NGSS Framework outlines each of the eight Practices. Practice number two is Developing and Using Models. Scientific models are representations of a system or parts of a system under investigation (Kenyon, Schwarz, & Hug, 2008). Models help students understand and create testable questions about the phenomena at hand. Models can and should be revised over time as students gather evidence and gain understanding about the science idea represented in the model (Ambitious Science Teaching, 2015). Models allow students to understand and make predictions about the world (NGSS Lead States, 2013). In short, "models are external representations of mental concepts" (Krajcik & Merritt, 2012).

Scientific modeling can be included in science instruction beginning in kindergarten. At the early grade levels, models typically consist of pictures, diagrams, or storyboards. When students progress in their ability to reason abstractly, they can begin to create models about more abstract concepts (NGSS Lead States, 2013). While many teachers use scientific models in the classroom, often students do not have to develop the models themselves. Rather, students reproduce models found in textbooks or on posters and they do not engage in the discovery process or solve problems when creating models (Ambitious Science Teaching, 2015). There is little connection between this type of modeling and the real process by which scientists come to develop understanding about a natural phenomenon (Krajcik & Merritt, 2012).

When teachers engage their students in scientific modeling, they address not only NGSS Practice 2, but most of the other eight Practices as well. When students create models, they are also asking questions, planning and carrying out investigations, analyzing and interpreting data, possibly using mathematical and computational thinking, constructing explanations, engaging in argument from evidence, and obtaining, evaluating, and communicating information (NGSS Lead States, 2013). The use of models is efficient use of time in the elementary science classroom. Unfortunately, elementary teachers may be intimidated by implementing scientific modeling in their classroom, in part due to their underpreparedness to teach science.

Elementary teacher preparation to teach science.

Elementary teachers are underprepared in science content knowledge. Halim and Meerah (2002) studied preservice teachers and found their ability to promote students' conceptual understanding of physics was limited by their content backgrounds. A weak content background led to teachers demonstrating difficulty in explaining scientific ideas as well as an inability to correct students' misconceptions. Other studies support these results, especially regarding teachers' promotion of student misconceptions when they lack a strong content background (Abd-El-Khalick & BouJaoude, 1997; Atwood & Atwood, 1996; Burgoon, Heddle, & Duran, 2010; Krall, Lott, & Wymer, 2009; Kruger, 1990; Kruger and Summers, 1988).

The 2018 National Survey of Science and Mathematics Education demonstrated that less than half of elementary teachers took college courses in chemistry, physics, or environmental science. While a majority of teachers took biology, only 1% of teachers reported taking an engineering class at the college level (Banilower, et al., 2018). Additionally, most entry-level science courses at the university level are not specifically designed for prospective teachers and the content taught in these courses may not be well-aligned with content they will later be required to teach (California Council on Science and Technology [CCST], 2010).

Feistritzer (2011) found that in 2011, 71% of elementary teachers in the United States held either a bachelor's or master's degree in Education with only 27% of elementary teachers holding a bachelor's or master's degree in a different discipline. (Their study did not specify in which other disciplines teachers received their degrees.) Additionally, multiple subject credential (for elementary teacher) programs vary significantly in how much, if any, coursework is specifically dedicated to science content and methods (CCST, 2010). For example, the multiple subject credential and Master's program at University of California, Irvine requires two courses dedicated to science curriculum and methods while the credential and Master's program at UCLA has no dedicated science courses (University of California, Irvine, 2015; University of California, Los Angeles, 2017). It can be presumed through this fact, along with the self-reported course-taking described above, that most elementary teachers have minimal exposure to the physical sciences prior to entering the classroom to teach. The physical sciences include physics, astronomy, chemistry/biochemistry, and the earth sciences (UCLA, 2016). Given that the National Science Teacher Association (NSTA) recommends that elementary teachers demonstrate competency in life, Earth, and the physical sciences, elementary teachers clearly need significant PD on science content following the completion of their preparation program to be prepared to teach science to their students (Trygstad, Smith, Banilower, & Nelson, 2013).

Elementary teachers' self-efficacy and confidence in teaching science.

Across content areas, literature has shown that elementary teachers consistently self-report low levels of confidence and self-efficacy related to teaching their students science (Adams, Miller, Saul, and Pegg, 2014; Amato, 2004; Dorph, et al., 2011; Fulp, 2002). In addition, research shows that when teachers have a negative attitude toward a topic, they can pass this attitude on to their students, ultimately affecting retention and enjoyment of the material (van Aalderen-Smeets & Walma van der Molen, 2015).

Bandura's social learning theory states that behavior occurs when people believe in their ability to perform their own behavior (1982, 1997). He called this self-efficacy. When teachers have high self-efficacy related to teaching science, they are more likely to engage in effective professional behavior which will positively affect student achievement (Pruski, et al., 2013). Bandura identified four main sources of influence on self-efficacy: mastery experience, vicarious experience, social and verbal persuasion, and affective state (1997). PD can provide an opportunity for teachers to experience all four of these. Specifically, in PD teachers have vicarious experience of observing someone model the strategies, they can have a mastery experience when they bring the strategies into their own classrooms, they can receive social and verbal persuasion from other participants or the leader, and their affective state may be positively changed if their anxieties around teaching science are lessened (Haymore Sandholtz & Ringstaff, 2014).

Traditional professional development and effective professional development.

The general purpose of teacher PD is to help teachers continually refine their skills and increase their knowledge base in both specific and general topic areas (Guskey, 2000). However, across content areas, teachers perceive traditional PD to be ineffective (Borko, 2004). Traditional PDs are frequently one-time workshops which are often disconnected from teachers' everyday experiences (Gulamhussein, 2013; Yoon, et al., 2007).

Though significant research has been conducted on what constitutes effective PD, the results of these studies have not generally been applied to PD practice. Research demonstrates that effective PD should be long-term/sustained and well-implemented (from Yoon: Garet et al., 2001, Supovitz, 2001, Wilson & Berne, 1999) and based on a solid theory of change related to teacher (adult) learning (Ball & Cohen, 1999). Corcoran, McVay, and Riordan (2003) determined that when teachers received 80 hours of science professional development, they were more likely to use the teaching practice learned than those who received fewer than 80.

The National Science Teacher Association released a position statement in 2006 outlining the principles of an effective PD program, including research-based elements such as "PD should be integrated and coordinated with other initiatives in schools and embedded in curriculum, instruction, and assessment practices" (NSTA, 2006, p.2). In addition, to meet NGSS requirements, PD topics need to be deeply embedded in the subject matter, involve the participating teachers in active learning, and be connected to teachers' own practice (Reiser, 2013).

Ramey-Gassert, Shroyer, & Staver (1996) determined that PD experiences also have a direct impact on teacher self-efficacy in teaching science. Haymore, Sandholtz & Ringstaff (2014) found that teacher self-efficacy scores on the Science Teacher Efficacy Belief Instrument (STEBI) increased significantly following one year of intensive science PD. At the beginning of their study, nearly half (46%) of participating teachers were unsure if they had the skills to teach science. By the end of the second year, only 10% still reported feeling unsure about their science teaching skills. Generally, elementary teachers report feeling less qualified to teach science than other content areas (see Banilower, et al., 2018; Fulp, 2002; Weiss, et al., 2001). When teachers are comfortable teaching science, they will spend more time teaching it and teach it in more creative ways (Westerback & Long, 1990).

The Study

Evaluating a science professional development program.

This study evaluated a science professional development program for elementary teachers in the Los Angeles Unified School District (LAUSD) called Engaging Young Minds (EYM). EYM sessions incorporated nanoscience content (e.g., physics and chemistry) along with scientific modeling strategies.

This program was chosen for study because it was highly successful in its sixth year of implementation, but no formal research had been conducted around the program in the past to determine the specifics behind its success. Each year, enrollment and interest increased to the point of necessitating a waitlist for potential participants. EYM went beyond the traditional one-shot PD structure providing teachers with four full days of workshops during the summer with optional follow up sessions during the school year. Additionally, for the 2016-2017 year, the combined foci of nanoscience content and scientific modeling was novel for elementary, but especially lower elementary grades and covered material that participating teachers likely did receive at other PDs.

The descriptive, mixed methods study of Engaging Young Minds will help program developers determine what parts of the program are working best, the extent to which teachers perceive participating in the program is affecting their confidence and content knowledge, and what parts are not helpful to teachers.

Research questions.

1. What do teachers report as changes to their science teaching following participation in EYM?

   a. Specifically, what changes do teachers report related to their use of scientific modeling?

2. To what extent is teacher self-efficacy related to teaching science changed by participating in EYM?
3. How do students respond to using scientific modeling to understand science content?
   a. In what ways is student use of modeling different from how they typically gain understanding of science content?

Research site and participants.

This project included teachers from elementary schools across LAUSD and interview participants from nine elementary schools in the greater Los Angeles area. Schools were all in the process of implementing the NGSS and teachers from these sites voluntarily participated in the PD.

The PD occurred throughout the 2016-17 school year. The main portion occurred at a Los Angeles middle school in summer 2016, and there were several optional follow up sessions occurring during the school year at various locations. It was overseen by the LAUSD coordinator of science instruction, Lillian Valadez-Rodela as well as Dr. Lynn Kim-John, the director of the Science Project at Center X at UCLA. EYM lasted four full days over the summer with continuous follow up sessions throughout the subsequent school year, totaling approximately 50 hours. Though this is less than the ideal of 80 hours, as demonstrated in the above-cited research by Corcoran, McVay, and Riordan (2003), there is a possibility that teachers will receive additional PD through their individual school sites or the district to approach or reach the 80 hours during the school year.

In addition, for the first time, the program included content sessions led by faculty from the California NanoSystems Institute (NSI) from UCLA. All elementary teachers who participated in EYM in summer 2016 along with teachers who participated in previous years and are still teaching at the elementary level were eligible to participate in the research study. A total of 124 teachers participated during summer 2016. More than 600 teachers participated in past cohorts as well.

A total of ten teachers participated in further research activities (e.g., interviews) at the end of the 2016-17 school year. These teachers were from a variety of K-6 classrooms, at different elementary school sites, around the Los Angeles area.

Research design.

The research was a qualitative study with supplementary quantitative data collected. A quantitative measure allowed me to collect data from the large number of teachers who participated in EYM during the previous several years to see trends and patterns across cohorts. A quantitative measure provided representative, if limited, data. Quantitative data alone, however, was insufficient to fully address my research questions.

Qualitative data revealed the story behind the quantitative response. It was necessary to probe deeper into the teachers' experiences to understand why teachers were or were not using techniques or resources they got from Engaging Young Minds. Gathering qualitative data helped explain teachers' behavior in their classrooms, revealing the context in which teachers work, and gave teachers a chance to clarify points.

Data collection.

I collected data using the following methods: a quantitative pretest-posttest survey, a quantitative single-administration survey, and interviews. In total, 10 teachers were interviewed in June and July, 2017 to determine how they perceived their confidence and classroom practice changed following participation in EYM, their comfort level around the nanoscience content, their perceptions of students' engagement with the material, and their use of scientific models in the classroom during the school year.

The survey was given as a pretest-posttest to teachers who participated in the 2016 EYM program, and teachers who participated in earlier years were invited to complete the survey as well in a single administration (not as a pretest-posttest). The survey for both 2016 teachers as well as previous participating teachers assessed teachers' feelings of preparedness to teach science and familiarity with the NGSS and teachers' understanding of scientific modeling. It included a survey developed by Hayes, et al. (2016) to measure use of the NGSS science and engineering practices, and selected questions from the Science Teacher Efficacy Belief Instrument (STEBI), a validated instrument developed by Riggs and Knochs (1990). The posttest administered at the end of the PD in summer 2016 included a question asking teachers to speculate how likely they were to use the content kit from the PD, if they were willing to be contacted for an interview later in the school year, and provided a space for teachers to give general feedback about the PD. For teachers who participated in previous years who completed the single survey, they were given similar end questions except the question related to using the content kit from the 2016 PD.

Significance of the project.

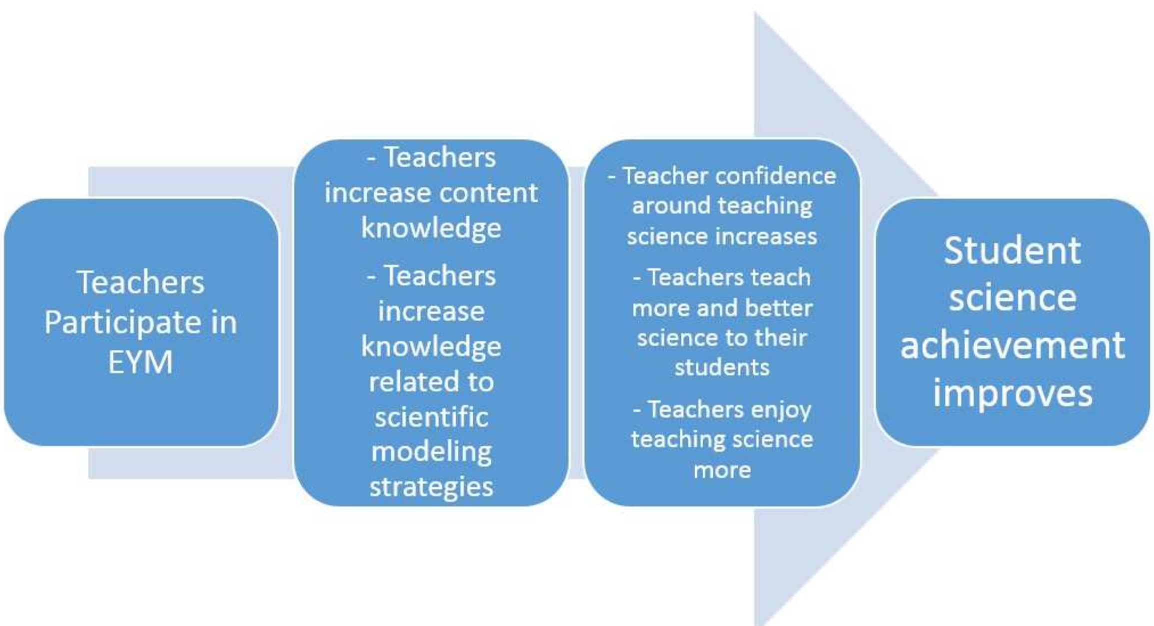
With the implementation of the Next Generation Science Standards, elementary teachers are being asked to teach both different and more science content to their students. Additionally, teachers will need to incorporate more rigorous teaching methods, along with developing students' abilities to create and use scientific models. This combination of changes will require teachers to participate in professional development and change their classroom practice.

Since teachers spend much time in professional development, we hope the sessions they attend are high-quality and provide teachers with tangible ways to improve their practice. In science specifically, developing teachers' self-efficacy and confidence is just as important as developing content knowledge. Others may benefit from being able to understand what types of PD content and activities are most helpful, especially within the context of the new science standards.

Chapter 2 – Literature Review

Given the new rigorous requirements built into The Next Generation Science Standards (NGSS), teachers need to participate in relevant professional development (PD) experiences to help them understand both what they are expected to teach as well as how they will be expected to teach it. NGSS-focused PD experiences will be most successful if they incorporate both science content and pedagogy. One such PD, Engaging Young Minds, blends both with a focus on improving teacher confidence and practice in teaching science. Figure 1. *Engaging Young Minds Theory of Change* shows the theory of change behind EYM.

Figure 1. Engaging Young Minds Theory of Change



My study investigated the extent to which teachers' self-efficacy and use of scientific modeling strategies in science lessons were affected following participation in EYM. Additionally, studying the PD helped determine which parts of the PD were most effective and which did not contribute to effective implementation to help improve the PD in the future. The following literature review will serve as a contextual frame for the study.

This literature review begins with an overview of the NGSS, including their development and requirements. Next, I will provide recent data related to science student achievement in the United States, and compared to other countries, along with why improving science achievement is important for students individually and the United States as a whole.

Following student science achievement, teacher preparedness to teach science is discussed. This includes information related to requirements for teachers to obtain certification and teachers' typical science content backgrounds. Additionally, teacher confidence and self-efficacy around teaching science, both of which affect teaching quality, are addressed.

Once teachers feel confident enough to increase the time they spend teaching their students science, it is important to ensure teachers are pedagogically prepared as well. In light of NGSS requirements, this includes incorporating scientific modeling strategies for science instruction, so scientific modeling is reviewed. Finally, the chapter concludes with implications for professional development (PD). Teachers will need to learn both science content and strategies through professional development throughout their teaching career to improve their science instruction.

Student Achievement in Science

Compared to students in countries around the world, students in the United States are underperforming in science. The Program for International Student Assessment (PISA) is administered to 15-year-old students in more than 70 countries and educational jurisdictions. The test is coordinated by the Organization for Economic Cooperation and Development (OECD). The PISA primarily tests students' scientific inquiry and explanation abilities including their ability to identify scientific issues, explain phenomena scientifically, and use scientific evidence (PISA, 2010, p. 126). It also tests students' content knowledge of physical systems, living systems, earth and space systems, and technology systems. In the 2012 administration, students in the United States received scale scores as well as proficiency levels. Students' scale scores were below the overall average and behind 27 other countries, including Canada, Australia, and the UK. Nearly 20% of students scored below a level 2 proficiency, which is the baseline level of proficiency as determined by the OECD.

Another standardized measure of science achievement, the Trends in International Mathematics and Science Study (TIMSS), measures students at grades 4 and 8 in the United States and 57 other countries and education systems. Each question on the TIMSS tests students' ability to use scientific processes as well as science content. In fourth grade, students are tested on life science, physical science, and earth science. In the eighth-grade administration, students are tested on the content areas of biology, chemistry, physics, and earth science. The 2011 administration of the TIMSS indicated that students in fourth grade scored above the overall average and behind only six other countries. However, the eighth-grade students' scores were similar to the PISA in that the United States' average score was above the overall average, but the US was still outperformed by 24 other countries and education systems. Students' score decline from fourth to eighth grade is a trend which has been observed repeatedly in analysis of international standardized tests (Poland & Plevyak, 2015; U.S. Department of Education, 2000).

The National Assessment of Educational Progress (NAEP), which is administered periodically to students around the country, assesses student performance in a variety of content areas, including science. The most recent available data from the 2011 administration of the NAEP describe student performance across three broad content areas: physical science, life science, and earth and space sciences. As is true with the TIMSS assessment, students are tested on both content and scientific reasoning ability in each question. In 2011, 32% of eighth graders tested scored at or above Proficient while only 2% of students tested scored at Advanced. One third of students scored Below Basic, the lowest achievement level in which students can score. Students who score Below Basic have failed to demonstrate even partial mastery of the topics on which they are tested[1]. Though these numbers were higher than results reported in 2009, this indicates that nationally, students are entering secondary school with an insufficient understanding of science content.

In California specifically, numbers are slightly better. In the 2015-16 school year, the only available statewide data for science performance was obtained by students in grades 5, 8, and 10 who took the California Standards Test (CST) in Life Science. Of those students tested, approximately half of students at each grade level received scores which qualified as Advanced or Proficient (54% in 5th grade, 61% in 8th grade, 50% in 10th grade) (CA DOE, 2016). Necessarily, this means that almost half of students in California are not proficient in topics across life science, earth science, and the physical sciences. Students also completed subject-specific end of course CST tests for physics, biology, earth science, and chemistry courses up through the 2012-13 school year. (The CST was replaced with tests aligned to the Next Generation Science Standards and the new tests were implemented for the first time in the 2018-2019 school year; students did not take official science tests in the interim years.) In these subject-specific tests, students demonstrated similar levels of achievement compared to the general science CSTs reported above. It is clear that nearly half of all students in California are not testing at a proficient level across science content areas beginning in fifth grade and continuing through high school. The specific scores for students in the Los Angeles Unified School District (LAUSD) are similar to those reported for the state of California. In 2016, 24%

[1] http://nces.ed.gov/nationsreportcard/glossary.aspx#basic

of fifth grade students, 26% of eighth grade students, and 30% of tenth grade students scored Below Basic or Far Below Basic on the general science CST (CA DOE, 2016).

Improving Student Science Achievement through the NGSS

Improving student performance in science has implications beyond standardized test scores. Hanushek, Peterson, and Woessmann (2012) analyzed student performance on the three standardized science tests mentioned above (PISA, TIMSS, NAEP) and concluded that while the U.S. has demonstrated moderate improvement over time, the rate of progress is too slow. Hanushek, Peterson, and Woessmann argue that 24 other countries appear to be improving their students' performance on mathematics and science assessments at a faster rate than the U.S. Furthermore, the U.S. does not seem to be improving at a rate which would allow it to reach achievement levels demonstrated by leading industrialized countries over time. Developing a scientifically literate population will help keep the U.S. globally competitive and provide students with the intellectual background they need to produce new ideas and inventions (see: Bybee, 2010; Feinstein, 2011; U.S. Department of Education, 2000). Additionally, the Department of Commerce estimated that STEM occupations will grow by 17%, compared to a 9.8% growth rate for non-STEM jobs, between 2008 and 2018 (Langdon, McKittrick, Beede, Khan, & Doms, 2011). In California specifically, an estimated 1.1 million jobs will require STEM degrees by 2018 and this number will only continue to increase for the foreseeable future (Carnevale, Smith, & Strohl, 2010).

To help prepare students to be scientifically literate and able to succeed in STEM-related jobs, the Next Generation Science Standards (NGSS) were introduced in 2011 (NGSS Lead States, 2013). The NGSS resulted from the need to improve both student achievement in science as well as improve the way science is taught to students, beginning at the elementary grades

(NGSS Lead States, 2013). Following the release of an initial draft of the framework and a period for timelines for the Standards and accompanying assessments, California adopted the NGSS in 2013 and is, theoretically, fully implemented with instructional materials adopted and assessments operational by the 2018-19 school year (CSTA, 2016).

The NGSS were developed by educators, policymakers, and content experts in twenty-six states and are comprised of three dimensions – Practices, Crosscutting Concepts, and Disciplinary Core Ideas (DCIs). In theory, when students learn and master all three of these dimensions, they will be proficient scientists. Practices refer to behaviors in which scientists engage when testing hypotheses and building models and theories. They are beyond scientific research skills in that one must have the skill plus knowledge specific to each practice. Crosscutting concepts are ideas which transcend specific disciplines, such as patterns, cause and effect, and energy and matter. The framework specifies that these concepts are vital for students because they help students integrate knowledge gained across subjects. Finally, DCIs are the main science content ideas which focus K-12 science curriculum. They are grouped into four categories: the physical sciences, the life sciences, the earth and space sciences, and engineering, technology, and application of science (National Research Council, 2012; NGSS Lead States, 2013).

The NGSS presents science curriculum as a spiral. That is, topics are introduced repeatedly over the course of a student's entire education, not just in one grade. Spiral instruction begins with the basic concepts in earlier grades and these are revisited with further details in later grades. For example, in kindergarten, students are introduced to the idea that different strengths or directions of pushes or pulls affect an object's motion in different ways. This idea is then further developed in third grade when students observe and/or measure an object's motion to provide evidence that a pattern can be used to predict further motion (NGSS Lead States, 2013).

Elementary teachers spend relatively few minutes on science instruction in their classrooms for two main reasons. First, as mentioned above, teachers will spend less time teaching a subject when they do not feel confident teaching the subject. This is compounded with the fact that teachers typically dedicate substantial classroom instructional minutes to English-language arts and mathematics (Griffith & Scharmann, 2008; Perie, Baker, & Bobbitt, 1997).

Nationally, teachers report spending just over two hours per week on science instruction (Blank, 2012). State averages vary widely. In California, a statewide study conducted by The Center for the Future of Teaching & Learning at WestEd in 2011 (Dorph, et al., 2011) concluded that students in California rarely receive high-quality science instruction because mechanisms to support such instruction are rarely in place. This report discovered that 40% of elementary teachers (grades K-5) reported spending 60 minutes or less per week on science instruction in their classrooms.

The implementation of the NGSS brings a renewed emphasis on teaching science in elementary classrooms. The exact impact on instructional minutes remains to be seen but teachers will implement more cognitively complex tasks and activities in their classrooms to address all elements of the NGSS. As seen with the implementation of Common Core State Standards and the accompanying testing, teachers will likely be incorporating more science instruction into their classrooms to cover the increased content to prepare for the tests which will accompany NGSS.

Research over the previous three decades has identified that elementary science teaching in the US primarily consists of much teacher lecture followed by students reading the text, taking notes, or completing worksheets (Crawford, 2000; Martin & Hand, 2009; Pratt, 1981; Stefanich, 1992; Weiss, 1994; U.S. Department of Education, 2000).

Though traditional methods such as teacher lecture and worksheets do serve a particular teaching purpose, these methods will not satisfy all science teaching requirements of the NGSS. Namely, these methods do not allow students to derive their own hypotheses and draw their own conclusions about the scientific phenomena at hand (NRC, 2012). Additionally, teachers do not often use inquiry-based methods, which are a tenet of the NGSS (NRC, 2012). Teachers must now think of science teaching as a process of inquiry and help students have a truly deep understanding of the concepts behind the facts. This will require less recitation of facts and more application of knowledge in context and requires teachers to move away from the conception of science as a body of disconnected facts (NRC, 2012; NSTA, 2014).

The widespread use of traditional teaching methods is most likely due to many teachers at the elementary level are lacking in both content knowledge (Weiss, 1994; Weiss, Banilower, McMahon, and Smith, 2001) and confidence (Adams, Miller, Saul, and Pegg, 2014; Amato, 2004; Dorph, et al., 2011; Jarrett, 1999; Rice and Roychoudhury, 2003) around teaching science content to their students. When these two issues combine, it can be expected that many elementary teachers do not enjoy teaching science. A lack of confidence may lead to teachers' lack of enjoyment of teaching science. For example, Wilkins (2009) surveyed 490 elementary teachers in the US and found that teachers reported science as their least-favorite and least-enjoyed subject to teach. Bauer & Toms (1990) found similar results when surveying New York City elementary teachers. When asked to rank five subjects in order of enjoyment of teaching, nearly half (45%) ranked science last.

Elementary Teacher Preparation to Teach Science

Teachers' enjoyment, or lack thereof, of teaching science is coupled with inadequate preparation in preservice teaching programs (Li, 2008; Schwartz and Gess-Newsom, 2008) as well as their own time as students in elementary and high school classrooms. A 2000 report by the National Commission on Mathematics and Science Teaching for the 21st Century found students in the United States receive woefully inadequate preparation in mathematics and science content (U.S. Department of Education, 2000). This report concluded that one of the major factors which would help improve student performance was providing better training for teachers. This is particularly important for elementary teachers given that the experiences students have during their elementary years potentially have the biggest impact on students' attitudes around and interest in science (Adams, Miller, Saul, and Pegg, 2014; Beane, 1988). For example, Pell and Jarvis (2001) administered surveys to elementary students assessing their attitudes related to being in school generally, science experiments, and what students thought about science. They found that students' enthusiasm for science steadily decreased as grade increased. Osborne (2003) found similar results in that student interest in science wanes beginning at age 11 and continues as students grow older.

Elementary teachers frequently graduate from teacher preparation programs or credential programs unprepared to teach the science content they need to impart on their students (Banilower, et. al, 2013; McDevitt, et al., 1993; Weiss, 2001). Few elementary teachers hold undergraduate degrees in science and/or science education. Unlike secondary teachers who typically receive single-subject credentials, elementary teachers receive multi-subject credentials. Consequently, elementary teachers take fewer content courses in STEM disciplines because they need a broad, not specialized, base of content knowledge (Banilower, et.al, 2013).

In the 2018 report of the National Survey of Science and Mathematics Education, conducted by Banilower, et. al (2018), only 3% of elementary teachers held a bachelor's degree in science. Holding a degree in the content area (e.g., science) does not guarantee success in teaching that content area, but many teachers have not taken any university-level courses in physics or chemistry and therefore do not have any background experience with some science content areas. Only 31% of teachers in the Banilower, et. al report (2018) indicated they completed at least one college course in physics and fewer than half of teacher (45%) reported completing a college-level chemistry course. Nearly 5% of elementary teachers reported having no coursework in life, Earth, or physical sciences (Trygstad, Smith, Banilower, & Nelson, 2013).

The National Science Teachers Association recommends that elementary teachers are prepared to teach content across life, earth, and physical science content areas (NSTA, 2003). In 2012, only 36% of elementary teachers met that standards (Banilower, et.al, 2013).

The type of school where teachers take their courses matters as well. Over one third of teachers reported completing at least one science course at the community college level (Banilower, et. al, 2013). Approximately 60% of teachers are completing lower-division requirements (including basic science) at the community college level. Research demonstrates that there is less content alignment with teacher preparation programs at two-year colleges compared to four-year institutions (CCST, 2010). That is, the content provided in science courses at two-year colleges is even less aligned to the content teachers are expected to teach compared to the content in science classes at four-year schools. Because community college is such a practical and popular option for many students, it is essential for teachers to continue their science learning after they leave the classroom.

Credential requirements vary for elementary teachers across the United States. Typically, teachers are required to complete a teacher preparation program after or in conjunction with completing a bachelor's degree from an accredited university. Many states require new teachers to complete a student teaching and/or first-year mentoring program. Finally, all states require teachers to complete a content assessment to theoretically ensure they are prepared to teach all elementary content areas.

Content tests vary by state, but can include the Praxis core content exam, which tests teachers' reading, writing, and mathematics content only (ETS, 2016). In California, teachers are required to pass a general knowledge test such as the California Basic Educational Skills Test (CBEST), which assesses basic reading, writing and mathematics skills. Additionally, credential candidates must pass the California Subject Examination for Teachers (CSET). Elementary teachers take the multiple-subject CSET which assesses multiple subject areas. For science specifically, the assessment determines competency in physical, life, and earth and space science in addition to teachers' ability to apply scientific tools (Commission on Teacher Credentialing, 2014). Teachers may take the CSET multiple times if they do not pass it the first time. Between 2003 and 2010, a total of 91% of all who attempted the multiple-subject CSET passed (which includes multiple exam sessions for the same teacher if they did not pass the first time).

It cannot be assumed that high passing rates on the CSET indicate that teachers are, in fact, adequately prepared to teach. A study by Buddin and Zamarro (2009) of the RAND Corporation showed that, in LAUSD specifically, teacher preparedness as defined by passing the CSET is not correlated with higher student achievement. Therefore, the high passing rates of the CSET do not indicate teachers are in fact prepared to teach their students. Rather, teacher quality is most positively affected by teacher experience along with teacher coursework in the subject area taught (Rice, 2003).

Teaching Self-Efficacy

Teachers' preparedness may also affect their self-efficacy. When teachers are fully prepared to teach a subject, this includes having strong content knowledge along with self-efficacy around teaching their students the content. When teachers have higher self-efficacy, they are more open to trying new methods in their classroom and show greater persistence and planning in their classrooms (Jerald, 2007). Additionally, Swackhamer, Koellner, Basile, & Kimbrough (2009) saw significant increases in in-service teachers' ratings of self-efficacy related to teaching science following participation in content-area courses.

Elementary teacher self-efficacy related to science can be notoriously low (Adams, Miller, Saul, and Pegg, 2014; Amato, 2004; Dorph, et al., 2011; Jarrett, 1999; Rice and Roychoudhury, 2003; Scharmann & Hampton, 1995; Tosun, 2000). In 2007, Neil, Murphy, & Beggs conducted interviews with 300 elementary teachers. Half of teachers interviewed cited a lack of confidence and ability to teach science. Additionally, elementary teachers report feeling less qualified to teach science than other academic areas. Only three in ten elementary teachers feel well-prepared to teach science, particularly physical science (Fulp, 2002). In addition to feeling unprepared in content, elementary teachers also feel less prepared to develop students' abilities to make connections between science and other disciplines along with leading their class in an investigative discovery (Fulp, 2002).

When teachers do not feel confident in teaching a particular subject to their students, they spend less time teaching it and student attitudes toward that content area are less positive (Munro & Elsom, 2000; Koballa & Crawley, 1985). Frenzel et al. (2009) found that teacher enjoyment is directly related to student enjoyment. That is, as teachers displayed more enthusiasm toward a subject, students also demonstrated more enthusiasm. Also, as one might expect, when teachers spend more time on a particular content, typically student achievement increases in that content area (Coates, 2003; Connor, Son, Hindman, & Morrison, 2005; Connor, Morrison, & Katch, 2004). As Blank (2012) found, less time teaching science is correlated with lower scores on both state and national science assessments. Specifically, in the 2009 4^{th} grade NAEP administration, the 13 states with the highest average NAEP scores spent, on average, more than three hours per week on science instruction in elementary classrooms (Blank, 2012).

General self-efficacy was a concept introduced by Bandura (1977, 1982, 1994, 1997) and is derived from his social learning theory. Bandura argued that what we believe in about our own abilities has significant effects on our behaviors (1982). General self-efficacy is defined as: "judgments of how well one can execute courses of action required to deal with prospective situations" (Bandura, 1982, p. 122). When teachers believe their ability to teach a subject, such as science, is lacking, they will develop a negative attitude toward that subject and consequently avoid teaching that subject as much as possible (Riggs & Enochs, 1990).

There are two main components of self-efficacy: outcome expectancy and self-efficacy expectation. One is motivated to perform an action if they believe the outcome will be positive (outcome expectation) and they have confidence in their ability to perform the action successfully (self-efficacy expectation). Increasing teachers' self-efficacy can result in a sort of self-fulfilling prophecy. The more teachers experience success in teaching, whether generally or subject-specific, their actions will be positively affected, and they will continue to experience success (Bandura, 1997).

The Science Teacher Efficacy Belief Instrument (STEBI), developed by Riggs and Enochs (1990) is based on the theory of self-efficacy set forth by Bandura. The STEBI measures two separate elements of self-efficacy, Personal Science Teaching Efficacy Belief (PSTE) and Science Teaching Outcome Expectancy (STOE).

Scientific Modeling Strategies in the Classroom

This section describes what is scientific modeling and provides a rationale for EYM to focus on this during its 2016 iteration. To meet the requirements embedded within the NGSS, elementary teachers will need to know the content which they teach their students as well as ensure they are incorporating the eight science and engineering practices, including the practice dedicated to scientific modeling, into their classes during science instruction (NGSS Lead States, 2013). The eight practices are provided for reference below.

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Through modeling, students engage in nearly all other science and engineering practices. Additionally, modeling spans science disciplines which supports the idea that modeling should play a significant role in science (Louca & Zacharia, 2015).

Modeling is the process by which a representation of a phenomena is consistently adjusted and altered given the evidence (Louca & Zacharia, 2015). When students engage in modeling in science lessons, they are creating a way for the “unseeable” or internal to be seen. For example, students in third grade may develop and revise models related to sound where they determine what are sound waves, the relationship between force and volume, and sound traveling through the air. Over the course of the unit, students revise their beginning ideas given the new information they are learning. Students' models are not expected to be accurate from the beginning. Rather, students are expected to collect evidence through the course of the science lessons and revise their models to be consistent with evidence (Krajcik & Merritt, 2012). Schwarz, et al. (2009) created a four-part practice of modeling: construct, use, evaluate, and revise. By engaging in this process, students are forming new scientific knowledge without simply memorizing facts (Halloun, 2006). This leads to students engaging in a much more authentic scientific process and helps students develop scientific literacy (Gilbert, Boulter, & Rutherford, 1998; Linn, 2003).

Additionally, studies show a positive relationship between student achievement and use of models (Miller, McNeal, & Herbert, 2010; Schwarz & White, 2005; Williams, 2011). For example, when a modeling-centered curriculum was implemented in a high school physics class, students demonstrated statistically significantly higher scores on the content posttest assessment in comparison to previous years (Schwarz & White, 2005). Myriad other studies demonstrate positive effects of modeling on student achievement.

Much of the research on modeling to date has been conducted on older learners (e.g., middle and high school, and beyond) so it is important to consider what modeling looks like for younger elementary students (Louca & Zacharia, 2015). It is particularly critical for elementary teachers to understand the science ideas their students are already bringing into the classroom. When teachers accurately gauge students' preexisting science ideas, it can be easier for the teacher to determine how best to help students revise their initial models (Ambitious Science Teaching, 2015).

Many teachers currently have a limited, or only partially accurate, perception of what modeling is and should look like in the science classroom (Aktan, 2016). While teachers do not necessarily have a negative attitude about using models, they do not know how to successfully implement them in their classrooms (Aktan, 2016). Consequently, teachers will need training and professional development in order to understand the task at hand with implementing this science and engineering practice from the NGSS.

Professional Development

If PD is long-term and high-quality it should help teachers consistently grow in science content knowledge and teaching strategies throughout their tenure as teachers. Most PD, however, does not meet this standard. Teachers perceive traditional PD to be ineffective across content areas. In a recent report released by The New Teacher Project (2013), less than one-half of teachers surveyed indicated that traditional PD helped them improve their teaching practice. Traditional PD sessions are frequently one-shot workshops which are often disconnected from teachers' everyday experiences (Gulamhussein, 2013; Yoon, et al., 2007). In the same New Teacher Project report (2013), teachers also indicated that insufficient PD led to feelings of isolation and lacking support.

The specifics in science are even more alarming. Though teachers indicate a substantial need for science content-focused PD, they also report a significant lack of access to such training (Banilower, et al., 2013; Fulp, 2002). In California specifically, 85% of elementary teachers reported participating in no science-specific professional development in the previous three years (Dorph, et al., 2011).

Though significant research has been conducted on what constitutes effective PD, there is a lack of application of the results of these studies to PD practice. Research demonstrates that effective PD should be long-term, consistent in focus, and well-implemented (from Yoon: Garet et al., 2001, Supovitz, 2001, Wilson & Berne, 1999) and based a solid theory of change related to teacher learning (Ball & Cohen, 1999). The National Science Teacher Association released a position statement in 2006 outlining the principles of an effective PD program, including research-based elements such as “PD should be integrated and coordinated with other initiatives in schools and embedded in curriculum, instruction, and assessment practices” (NSTA, 2006).

Several studies have investigated the effects of well-designed and implemented PD on teacher outcomes. Sandholtz and Ringstaff (2014) demonstrated positive effects on teachers’ self-efficacy in teaching science as well as changes in classroom practices following a three-year, intensive PD program.

Summary

In response to the increased need to improve science achievement in the United States, the NGSS were developed. However, both teachers and students are underprepared in the sciences so it is important to address both sides of this equation. When teachers feel more prepared, confident, and knowledgeable, they can move beyond traditional lesson styles to incorporate more advanced contents and teaching methods into their classrooms, regardless of grade level. One way to help prepare teachers to do this is to provide PD and determine its effects on teachers and their students leading to the goal of improving future iterations of the PD to expand its positive impact on participating teachers.

Chapter 3 - Design and Methods

This project is a descriptive study of a science professional development (PD) program that is built from a partnership between Center X at UCLA and the elementary science instruction division of LAUSD. The PD focuses on several key areas: teacher science content knowledge (particularly in nanosciences), teacher confidence and self-efficacy around teaching science, and incorporation of modeling strategies into science lessons. As discussed in Chapter 2, scientific modeling is an integral part of the new science teaching pedagogy that accompanies the NGSS. The ultimate goal is to improve teacher confidence and knowledge in teaching science through targeted content sessions and provide teachers with tangible modeling strategies to use in their classrooms. Evaluating the PD program will help to determine which parts of the PD have the greatest effect on teacher confidence and findings will help improve the PD in the future.

Table 1. Research Questions

Research Question	Data Collected to Answer Question	Sample Size
1. What do teachers report as changes to their science teaching following participation in EYM?	Estimated changes – posttest surveys Actual changes – interview questions 5 & 6	n = 86 n = 10
1a. Specifically, what changes do teachers report related to their use of scientific modeling?	Interview questions 8, 9, 9a, 10	n = 10
2. To what extent is teacher confidence/self-efficacy related to teaching science changed by participating in EYM?	Pretest/posttest surveys Single-administration surveys Interview questions 3, 4, 4a	n = 86 n = 26 n = 10
3. How do students respond to using scientific modeling to understand science content?	Interview questions 10, 11, 12	n = 10
3a. In what ways is student use of modeling different from how they typically gain understanding of science content?	Interview questions 10, 11, 12	n = 10

Research Design

The study used mixed methods, specifically interview and descriptive survey data. In the quantitative portion of the study, I collected data which provided a broad perspective on teachers' experiences with science and their experiences in EYM. The survey determined the average participant in terms of preparedness, use of modeling strategies, and confidence as a science teacher. However, it was also necessary to probe more deeply into a smaller sample of teachers' experiences to understand teachers' evolution as science teachers and why they are or are not using techniques or resources that are provided by Engaging Young Minds. The qualitative portion of the study provides a more in-depth understanding of teachers' experiences implementing what they learned at the PD as well as probe for further insights into teachers' experiences in the classroom and determine student perceptions of scientific modeling.

Gathering both quantitative and qualitative data determined what types of teachers are participating in EYM; how confident were teachers in their science teaching; helped explain teachers' experiences with science lessons in their classrooms; revealed the context in which teachers were working; and gave teachers a chance to clarify information collected on the survey.

Research Site and Population

The summer PD occurred at a Bell Gardens middle school and was overseen by the LAUSD coordinator of science instruction, Lillian Valadez-Rodela, as well as Dr. Lynn Kim-John from Center X at UCLA. The PD was open to both teachers who had participated in EYM in previous years as well as teachers who had never participated in EYM. Over the four days of the program, teachers participated in whole group and small-group breakout sessions as well as heard several speakers, including a faculty member from the California NanoSystems Institute

(NSI) from UCLA. The NSI is comprised of researchers at both UCLA and UC Santa Barbara (UCSB) dedicated to encouraging collaboration within industries of life and physical sciences, engineering, and medicine. Most elementary teachers have little, if any, background knowledge in these areas of the sciences.

Whole group sessions consisted of topics related to both scientific modeling and nanotechnology. Teachers had an opportunity to participate in a nanotechnology activity themselves and develop and revise a model over the last three days of the PD. Breakout sessions were exclusively designed to provide teachers with more in-depth engagement with scientific modeling to understand science.

No research or evaluation had previously been conducted on the EYM PD. Since it is a partnership program between LAUSD and UCLA, both entities were interested to see if teachers were satisfied with the PD and if it affected their classroom practice, as well as how it can be changed or improved for future administrations.

Los Angeles Unified School District and participants' schools[2].

All participants, both survey and interview, taught at schools in Los Angeles Unified School District (LAUSD). LAUSD is the second-largest school district in the United States and enrolled over a quarter million K-6 students during the 2018-2019 school year. In the 2012-2013 school year (the final year CST science scores were available), at least 45% of 5^{th}, 8^{th}, and 10^{th} grade students who completed the general science CST scored Basic, Below Basic, or Far Below Basic, indicating nearly half of all students did not demonstrate proficiency in this academic area.

[2] Data for this section were obtained from Ed-Data.org, L.A. Unified Fingertip Facts, and the National Center for Education Statistics (NCES).

As detailed below in Table 2, across the district, 74% of students identified as Hispanic/Latino ethnicity, 23% were English Language Learners, and 81% received free/reduced price lunch (a proxy measure for socioeconomic status). In comparison, across the school sites for the interview participants, an average of 59% of students identified as Hispanic/Latino ethnicity while 18% were English Language Learners and only 67%, on average, received free/reduced price lunch.

Mostly, interview participants' sites had significantly different (both higher and lower) percentages of students who identified as Hispanic/Latino as well as significantly different (again, both higher and lower) percentages of students who received free/reduced price lunch. Consequently, while interview participants are from a diverse group of schools, these schools do not necessarily align with the average LAUSD school, which could be interpreted as a strength – namely, maximizing of the variation of teachers' experiences.

Table 2. LAUSD and Site Demographic Information

LAUSD - Overall						
Total Students (K-6)	Total Students (K-12)	% Hisp/Latinx	% Black/Afr Am	% White	% English Leaners	% Free/Red Lunch
319,014	571,855	74%	8%	10%	23%	81%
Interview Participant Schools						
School Type	Total Students	% Hisp/Latinx	% Black/Afr Am	% White	% English Leaners	% Free/Red Lunch
Public STEM magnet	392	93%	0.5%	1.3%	20%	81%
Public & gifted/high ability magnet	571	86%	0.7%	4.7%	15%	79%
Private	221	0%	0%	99%	Data Unavailable	
Public/charter (Grades K-9)	2,962	99%	0.6%	0.4%	26%	98%

Public/charter	535	9%	3%	76%	3%	11%
Public/charter	738	19%	3%	42%	6%	21%
Public	868	98%	0.1%	1%	34%	93%
Public/magnet (Grades 4-12)	2,085	35%	4%	39%	2%	57%
Public/STEAM Local Initiative School	462	90%	0.2%	7%	39%	92%

Sample Description and Demographic Characteristics

Survey participants – pre-post surveys.

All elementary teachers who participated in EYM in summer 2016, along with teachers who participated in previous years and are still teaching at the elementary level, were eligible to participate in the quantitative portion of the research study. A total of 120 teachers participated during summer 2016. Of the 120, 96 teachers completed a pretest, 91 teachers completed a posttest, and 86 of these teachers completed both a pretest survey and a posttest survey for a complete response rate of 72%. The majority of the 86 respondents (60%) indicated they would be teaching third, fourth, or fifth grade during the 2016-17 school year. Only two teachers indicated they would be teaching sixth grade. Teachers were asked to provide the total number of years they had taught any grade level as well as the total number of years they had taught at the K-6 level. While these two numbers were the same for many teachers, this was not true for all. Consequently, teachers had taught at any grade level for an average of 16.5 years and at the K-6 level for 16.1 years.

Respondents were asked to indicate if they had participated in any of the previous EYM sessions beginning in summer 2012. Most teachers had not participated in any of the prior EYM sessions, but 21 teachers indicated they had participated in one or two prior EYM sessions and four teachers indicated they had previously participated in three EYM sessions. Two indicated they had participated in all four previous EYM sessions.

Survey participants – one-time survey.

A majority of teacher respondents taught Kindergarten, 4th, or 5th grades (n = 17). All teachers who completed the survey had taught at any grade level (K-12) for a minimum of nine years and the group as a whole had taught for an average of 19.2. When asked how long they had been teaching at the K-6 level, the average number of years declined slightly to 18.9 years. Of the 26 respondents, 12 had participated in one prior EYM session, 10 had participated in two prior EYM sessions, and 4 had participated in three prior EYM sessions.

Interview participants.

A total of 10 teachers who completed the pretest and posttest also participated in interviews. Teachers were from different schools around LAUSD. Table 3 below outlines the demographic characteristics of the interview participants. The ten teachers who participated in the interviews were comprised of eight females and two males. Their years of teaching experience ranged from four to 26, with an average of 17 years of experience in the classroom. One teacher taught at a private school. Two teachers taught at schools where the majority of the science instruction was completed by a designated science teacher and not themselves, but the interviewees did still engage in enough science with their students to participate in the interview. The remaining seven teachers taught at public schools and were their students' only science instructor.

Table 3. Interview Participants

Teacher Code Name	Grade level taught during 2016-17 school year	Number of years of K-12 teaching experience	Type of school
Anita	4th	23	Public STEM magnet

Alyssa	5^{th}	16	Public & gifted/high ability magnet
Evelyn	2^{nd}	26	Private
Faith	1^{st}	4	Public/charter
Jane	2^{nd}	24	Public/charter
Mindy	2^{nd}	8	Public/charter
Miranda	Kinder	20	Public
Miriam	$4^{th}/5^{th}$	20	Public/magnet
Michael	$4^{th}/5^{th}$	12	Public/STEAM Local Initiative School
Sam	1^{st}	20	Public/STEAM Local Initiative School

Survey Administration

Below is a description of the administration process of the pretest-posttest survey and the one-time survey. The survey consisted of six sections: demographic characteristics; feelings of preparedness to teach science; familiarity with NGSS practices; the teacher's definition of scientific modeling; measuring instructional practice (related to NGSS practices); and confidence around teaching science. The full survey instruments can be found in Appendix A.

Pretest-posttest administration.

The pretest-posttest survey was administered via paper and pencil to teachers at the very beginning of the first day of the summer 2016 session of the PD and during the latter half of the last day of the PD, allowing maximum time between administrations. The posttest asked teachers to indicate how likely they were to use the science kits received at EYM in their classrooms during the school year; the likelihood of participating in EYM follow up sessions during the school year; if they were willing to participate in an interview; and if they were willing to share samples of student work from the science lessons related to the nanoscience content.

One-time administration.

The one-time survey was emailed to all teachers by the who had participated in EYM previously and had a valid email address in May and June, 2017. Emails were sent from the EYM Program Manager directly to teachers to maximize likelihood of responses.

The purpose of the survey was threefold. First, the survey included demographic data related to teachers' years of experience in the classroom their feelings of preparedness on a 1-5 Likert scale to teach different science topics. Teachers also rated familiarity, also on a 1-5 Likert scale, with each of the eight NGSS science and engineering practices. Second, I asked teachers to provide their own definition of scientific modeling and then complete a survey developed by Hayes, Lee, DiStefano, O'Connor, & Seitz (2016) which measures teachers' use of various science instructional practices. The science instructional practices survey asked teachers to rate how often their students engage in certain behaviors during science lessons as well as how often teachers themselves engage in certain behaviors when teaching science lessons. Answers were provided on a 1-5 Likert scale indicating frequency for each item.

The final portion of the survey was the Science Teacher Efficacy Belief Instrument, or STEBI. The STEBI assesses two components of teachers' confidence around teaching science: self-efficacy and outcome expectancy. Self-efficacy refers to one's belief in their ability to perform the behavior (e.g., teach science) while outcome expectancy refers to one's belief that specific behaviors will result in desired outcomes. The STEBI is a validated, reliable instrument (see Enochs & Riggs, 1990). The final section of the survey asked teachers to provide 1-5 Likert scale responses to items assessing teachers' enjoyment of teaching science.

These surveys were administered via paper and pencil to the 2016 cohort and administered electronically to previous cohorts via the SurveyGizmo platform. The director of the PD, Dr. Kim-John, collected email addresses of all previous participants so they were contacted via email to request their participation in the data collection. The EYM Program Manager sent an initial email to past participating teachers with the survey link in fall 2016 and left the survey open for one month to allow teachers time to respond. Two follow up emails were sent to teachers who have not completed the survey – one two weeks following the first email and one five days following the first follow up. The Program Manager sent the initial contact email, in which he introduced me, along with the follow up emails. Given the potentially sensitive nature of these questions, a self-report survey instrument is most appropriate given that people are more likely to answer questions honestly through self-report as opposed to through an interview-style setting (see: Dillman, 2007, p. 38). This sample provided representative data of the total teachers who participated in EYM. There are necessarily limits to the type of data which can be collected, however. Quantitative data alone was insufficient to fully address my research questions.

Interviews.

The purpose of the semi-structured interviews was to gain further insight into changes teachers have seen made in their science instruction (especially given the new implementation of the NGSS) and changes they have seen in their students' science performance following their participation in EYM. Interviews took place over the phone and were semi-structured. Each interview was between 30 and 60 minutes. They were audio recorded and then transcribed. Teachers who completed both the pretest and posttest surveys at EYM were asked on the posttest survey if they would be willing to participate in a follow-up interview about their experiences integrating scientific modeling into their classrooms during the 2016-2017 school year. A total of 28 teachers indicated they would be willing to participate in an interview. These 28 teachers were emailed several times to garner as much response as possible. Of the 28 who indicated they would be willing to participate in an interview, a total of ten teachers comprised the final interview sample. The remaining 18 either declined to participate or did not respond to multiple contact attempts.

Interviews were conducted via phone during June and July 2017. One of the benefits of conducting the interviews after the school year had finished was that teachers were able to speak to the entire experience during the course of the year, not just the first half or three-quarters. Teachers were sent an informed consent prior to the interview and were asked to sign and digitally return the consent form. Each teacher consented to being audio-taped during their interview for transcription purposes.

Student work.

To triangulate how interviewed teachers are implementing modeling strategies in their classrooms, I intended to invite teachers to share student work around modeling. Specifically, they were asked to provide initial, revised, and final student models from the superhydrophobic nanoscience content lessons. However, teachers were not able to provide this type of data because there was minimal implementation of scientific modeling and none were able to implement the nanoscience content in their classrooms. Consequently, teachers were asked to explain why they were unable to implement this in their classrooms.

Data Analysis

Surveys.

On the pretest-posttest survey, completed by teachers in the 2016 cohort, I conducted basic descriptive analyses of the demographic data. In addition, I was able to compare answers from the pretest and posttest administrations of the survey on items regarding feelings of preparedness and familiarity with NGSS practices. Additionally, I compared teachers' open-ended definitions of scientific modeling on the pretest survey compared to posttest responses.

Using SPSS, means and standard deviations were calculated for Likert-scale questions from the second portion of the survey related to scientific modeling practices as well as the items from the STEBI. The STEBI portion of the survey consisted of a deliberately chosen sample of items from the larger 25-item scale where respondents provided answers on a 1-5 Likert scale. Each of the items fell into one of two constructs – self-efficacy or outcome expectancy. Some items were reverse-coded. Average scores were calculated for respondents and compared from pretest to posttest.

I conducted similar analyses for the single-administration survey, including calculating means and standard deviations for Likert-scale questions. Where appropriate, I compared responses on items on the pretest-posttest surveys to responses on the same items on the single-time surveys. I chose to compare responses from the pretests to responses to the single-time surveys given that the two groups would be generally similar (e.g., they had not participated in the 2016 session of EYM when they completed the surveys). To compare these responses, I conducted independent samples *t*-tests (with equal variances not assumed).

Interviews.

Following the interviews, audio files were transcribed through Rev.com, and I completed a multi-step coding process for each interview. First, I read through each interview transcript twice to familiarize myself with each interview. No official coding occurred during the first read-throughs. Then, following the two read-throughs, I created my initial coding buckets. These, unsurprisingly, corresponded around my question themes and consisted of:

- Confidence and Comfortability Teaching Science

- Scientific Modeling
- Changes to Classroom Practice Following EYM
- General Thoughts on How Elementary Science Is Structured and Taught
- Areas of Strength and Areas for Improvement for EYM

During a third read-through, I began categorizing statements into the above areas. I would read each transcript and highlight statements and mark them with the corresponding code letter to indicate into which coding bucket they fell. During this third read-through, I also created sub-categories for several of the main ones:

- Changes to Classroom Practice Following EYM
    - Increase in time to complete science lessons
- General Thoughts on Elementary Science
    - Integrating content (teaching science along with math, language, arts, social studies, art)
- Areas of Strength and Areas for Improvement for EYM
    - Nanoscience content (specifically, inability to implement)

Finally, I created an Excel document with tabs for each of the overall coding themes. I read through each interview again five times. Each time, I specifically looked for the statements corresponding to each coding theme and added others that I had not previously coded but decided should be included in a bucket. For the sub-categories that I created following my initial coding, I highlighted the statements in the overall coding theme to indicate which ones corresponded to the sub-themes.

Chapter 4 - Results

Introduction

This chapter includes the findings and analysis of the surveys and interviews to answer my research questions:

1. *What do teachers report as changes to their science teaching following participation in EYM?*

a. Specifically, what changes do teachers report related to their use of scientific modeling?

2. To what extent is teacher self-efficacy related to teaching science changed by participating in EYM?

3. How do students respond to using scientific modeling to understand science content?

a. In what ways is student use of modeling different from how they typically gain understanding of science content?

Survey Results

Both the pre-post survey and single administration survey contained questions regarding feelings of preparedness to teach particular science topic areas, familiarity with the eight NGSS Practices and an open-ended space for teachers to provide their definition of scientific modeling. Additionally, participants responded to questions related to frequency of implementation of student practices in the classroom and teacher instructional practices in the classroom. These were derived from the survey tool designed by Hayes, et al. (2016) to assess science instructional practice in the age of NGSS. Finally, a selection of items from the Science Teacher Efficacy Belief Instrument (Riggs & Enochs, 1990) were included to assess teachers' Personal Science Teaching Efficacy Belief (PSTE) and Science Teaching Outcome Expectancy (STOE).

I began with surveying all teachers who participated in the 2016 EYM session at both the beginning of the week and end of the week and derived my interview sample from this group of teachers. Additionally, I surveyed past EYM participants.

Preparedness to teach science.

Teachers indicated how prepared they felt to teach both science in general as well as specific sub-topics on the pretest and the posttest. On the pretest, teachers were asked to indicate on a 1-5 Likert scale how well their education and teacher preparation programs prepared them for this. On the posttest, teachers were asked to indicate how well the EYM program prepared them. Higher scores indicated higher feelings of preparedness with a maximum of 5. A paired-samples *t*-test was calculated for each topic. Results indicated that teachers felt significantly more prepared to teach science overall as well as each of the subtopics at the time of the posttest (see Table 4).

Table 4. Teacher Feelings of Preparedness – Pretest-Posttest

	Pretest mean	Posttest mean	*t*-test (df)	p-value
Prepared to teach science overall	2.76	4.73	15.70 (85)	<.001
Prepared to teach physical sciences	2.55	4.12	10.49 (84)	<.001
Prepared to teach earth/space sciences	2.67	4.27	11.56 (85)	<.001
Prepared to teach life sciences	2.79	4.29	10.62 (83)	<.001
Prepared to teach topics related to engineering	1.88	4.37	20.88 (83)	<.001

On the single-time survey, teachers responded to two sets of questions regarding preparedness. Similar to the pre-post survey, teachers were asked to rate how their education and teacher preparation programs prepared them to teach science overall as well as specific sub-topics and how EYM prepared them to teach these things. As shown below in Table 5, teachers also consistently rated EYM higher, as teachers did on the pre-post survey, indicating that their feelings of preparedness were more impacted by attending EYM than their education/ teacher preparation program. This was most pronounced in the areas of topics related to engineering and teaching the physical sciences.

Table 5. Teacher Feelings of Preparedness – Single-Administration

	Education/ teacher prep mean	EYM mean	*t*-test (df)	p-value
Prepared to teach science overall	3.12	4.23	4.08 (25)	<.001
Prepared to teach physical sciences	2.85	4.00	4.57 (25)	<.001
Prepared to teach earth/space sciences	2.92	3.92	3.61 (25)	<.001
Prepared to teach life sciences	3.00	3.92	3.40 (25)	<.001
Prepared to teach topics related to engineering	2.23	4.27	6.45 (25)	<.001

Familiarity with NGSS practices.

Respondents were also asked to indicate their familiarity with all eight NGSS practices both at pretest and at posttest. Respondents were asked to indicate on a 1-5 Likert scale their familiarity, ranging from not at all familiar to extremely familiar. From pretest to posttest, teachers indicated statistically significant increases in familiarity with all eight NGSS practices. The largest reported increase was for Practice 2, developing and using models (see Table 6).

Table 6. Familiarity with NGSS Practices - Pretest-Posttest

	Pretest mean	Posttest mean	*t*-test (df)	p-value
Familiar with Practice 1: Asking questions and defining problems	2.74	4.01	9.61 (84)	<.001
Familiar with Practice 2: Developing and using models	2.66	4.24	11.07 (84)	<.001
Familiar with Practice 3: Planning and carrying out investigations	2.89	4.01	8.26 (84)	<.001
Familiar with Practice 4: Analyzing and interpreting data	2.82	4.04	8.84 (84)	<.001
Familiar with Practice 5: Using mathematics and computational thinking	2.82	3.93	9.16 (84)	<.001

Familiar with Practice 6: Constructing explanations and designing solutions	2.76	4.05	10.27 (84)	<.001
Familiar with Practice 7: Engaging in argument from evidence	2.85	4.14	9.53 (84)	<.001
Familiar with Practice 8: Obtaining, evaluating, and communicating information	2.74	4.01	9.61 (84)	<.001

On the single-time survey, teachers' ratings of familiarity indicated that they were mostly familiar with all eight practices. These results were compared to the mean responses to the same items on the Pretest to determine if there was a difference between teachers' responses.

Interestingly, when compared to the Pretest mean values, teachers on the single-time survey demonstrated much higher ratings of familiarity. This may be a result of the pretest-posttest teachers completing their survey at the beginning of the 2016-2017 school year and single-time survey teachers completing the single-time survey at the end of the 2016-2017 school year. The single-time group may have had more exposure to and work with the NGSS practices during the course of the year given that the implementation timeline for the NGSS in LAUSD would have been underway in classrooms during the 2016-2017 school year.

Table 7. Familiarity with NGSS Practices – Single-Administration

	Single Mean	Pretest mean	*t*-test (df)	p-value
Familiar with Practice 1: Asking questions and defining problems	3.85	2.74	4.00 (43.11)	<.001
Familiar with Practice 2: Developing and using models	3.85	2.66	3.95 (38.65)	<.001
Familiar with Practice 3: Planning and carrying out investigations	3.96	2.89	3.71 (42.54)	<.001
Familiar with Practice 4: Analyzing and interpreting data	4.00	2.82	4.08 (39.76)	<.001
Familiar with Practice 5: Using mathematics and computational thinking	3.85	2.82	4.04 (38.71)	<.001
Familiar with Practice 6: Constructing explanations and designing solutions	3.88	2.76	4.36 (35.95)	<.001

Familiar with Practice 7: Engaging in argument from evidence	3.92	2.85	4.30 (40.66)	<.001
Familiar with Practice 8: Obtaining, evaluating, and communicating information	3.92	2.74	3.91 (41.05)	<.001

Scientific modeling definition.

Teachers were asked to provide their own definition of scientific modeling at the pretest and at the posttest. Of the 96 completed pretest surveys, only 45 teachers provided a definition on the pretest. This number increased to 67 teachers who provided a definition on the posttest. In addition to seeing a significant increase in the number of teachers who provided a definition, the content of teachers' definitions shifted dramatically from pretest to posttest.

Definitions on the pretest were typically shorter than definitions on the posttest. On the pretest, most teachers wrote either one sentence or a short phrase. Multiple teachers included references to the "scientific method" or mentioned testing a hypothesis in their pretest definition. In addition, many teachers included the word "model" in their pretest definition but did not specify what type of model (e.g., visual) to which they were referring. Further, only two teachers included any mention of models being revisable over time or revising the model given new information. Some key words which were included in pretest definitions were scientific method, representation, real world, model, and demonstration. However, these were not used consistently in teachers' definitions nor were they used in the same way. For example, one teacher's definition was "*Making a visual that represents something in science*" while another wrote "*You can create a model to represent something (test something)*." In their pretest definitions, very few teachers referenced using models to demonstrate understanding underlying a concept. Rather, most definitions referenced using models to simply show a concept.

On the posttest, in addition to more teachers providing a definition, definitions were uniformly longer and demonstrated significant increase in understanding around what scientific modeling is and looks like. Many teachers wrote multiple or complex sentences in their definitions. The majority of teachers referenced scientific models to be revisable over time given new information or data from investigations/experiments. Nearly every teacher began their definition with clarifying that scientific models are used to represent a scientific concept. Many teachers referred to scientific "phenomena" in their definitions. Other keywords/phrases seen across definitions included simplifying the complex, drawing, explain, physical world, understanding, and visual. Definitions were also more consistent across on the posttest compared to the pretest. For example, many teachers wrote something similar this definition: "*Scientific modeling is the ability to create a representation to explain one's thinking and new learning. It is continuously revised based on new knowledge acquisition (discussion, text, etc.)*."

On the single-time surveys, teachers provided definitions of scientific modeling that were similar to the definitions teachers provided on the pretest survey. Of the 26 total surveys completed, only 14 respondents provided any response at all. Of the responses given, three teachers indicated that they could not provide a definition or had never heard of the term scientific modeling previously. One respondent wrote, "*I'm not familiar with this term, however, I would guess that it has something to do with use of models, or modeling something, maybe where doing an actual experiments or activity is not reasonable in classroom situations*."

The majority of the remaining respondents provided short, basic definitions, often incorporating the word "model" into the definition itself. For example, one teacher wrote, "*Scientific modeling is the use of models in science to show ideas*." Another stated, "*Representing understanding of a scientific concept (how things work) with a drawing, model, or* *picture*." One respondent mentioned the scientific method, but also clarified that they were unfamiliar with the term scientific modeling: "*I can think about it as modeling the scientific process to my students so they then can follow the process themselves. I can also think of it as using models to describe concepts in science. Honestly I don't think I've heard the term used that way*."

The most complete definition a teacher provided was: "*Scientific modeling for young children can be communicating, sketching & or building their models pertaining to a concept/phenomena. At young ages, scientific modeling reveals students' thinking*." None of the respondents included the idea of models being revisable or using evidence to make revisions. Additionally, only the one respondent quoted above incorporated the word "phenomena" into their definition. These results are not surprising given that the teachers who completed the single-time survey participated in versions of EYM which did not focus on scientific modeling.

Measuring instructional practice – student activities.

To measure instructional practice, teachers were asked to indicate the frequency at which students engaged in certain activities in their classrooms. On the pretest, teachers indicated how often students engaged in these activities, thinking retrospectively. On the posttest, teachers were asked to indicate how often they thought their students *would* engage in those same activities in the coming year. This allowed for determining if there was a difference in teachers' intent to engage in activities associated with scientific modeling following participation in EYM.

From pretest to posttest, teachers indicated they were statistically significantly more likely to have their students engage in all activities listed. The activities with the greatest difference from pretest to posttest are provided in Table 8 below (see Appendix D for a complete list). While the greatest difference was seen for having students use models to predict outcomes, the other items related to models and modeling showed smaller (though still statistically significant) increases.

The other items which showed the greatest increase from pretest to posttest related to having students critique each other's' reasoning, supply evidence to support a claim, and consider alternate explanations.

Table 8. Student Activities - Pretest-Posttest

	Pretest mean	Posttest mean	*t*-test (df)	p-value
Use models to predict outcomes	2.32	3.72	12.3 (81)	<.001
Respectfully critique each other's reasoning	2.94	4.17	12.1 (82)	<.001
Supply evidence to support a claim or explanation	3.12	4.28	11.8 (82)	<.001
Consider alternative explanations	2.93	4.08	11.5 (82)	<.001

On the one-time survey, teachers indicated their students most often engaged in generating questions, making and recording observations, supplying evidence to support a claim, and writing about what they observed and why it happened. When comparing single-time survey respondent answers on these items to the values on the same items on the pretest, teacher responses on the pretest were lower for three of the four items. The only student behavior where responses were similar was students' generating of questions or predictions to explore. This means that for both groups, teachers indicated their students developed questions or predictions at more or less equal rates. However, for the other three items, teachers who completed the single-time survey indicated their students engaged in each of the behaviors more frequently than did teachers who completed the pretest-posttest. For example, teachers who completed the single survey perceived that their students made and recorded observations more often than teachers who completed the pretest-posttest.

Table 9. Student Activities - Single-Administration

	Single-time mean	Pretest mean	*t*-test (df)	p-value
Generate questions or predictions to explore	3.92	4.15	1.20 (33.5)	0.24
Make and record observations	3.85	3.39	3.29 (62.2)	.002
Supply evidence to support a claim or explanation	3.69	3.12	2.84 (39.2)	.007
Write about what was observed and why it happened	3.69	3.29	2.47 (40.8)	.018

Measuring teacher instructional practice – teacher activities.

In addition to student activities, teachers also indicated the frequency with which they engaged in certain activities in their science teaching practice in the classroom. As with the questions related to student activities, teachers were asked at pretest to indicate how often they engaged in these activities, thinking retrospectively, and at the posttest, teachers were asked to indicate how often they thought they would engage in those same activities in the coming year. Similar to their ratings of student activities, teachers again indicated they were statistically significantly more likely to engage in all but two of the activities listed. The items with the greatest change from pretest to posttest are shown in Table 10 below (see Appendix E for a complete list). The item which showed the greatest change from pretest to posttest asked about teachers' intent to talk to students about the things they do in their lives outside of school related to science, which relates to modeling in that students' initial models are often crafted based on ideas generated outside the classroom.

Table 10. Teacher Activities - Pretest-Posttest

	Pretest mean	Posttest mean	*t*-test (df)	p-value
Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)	3.21	4.29	12.22 (83)	<.001

Discuss students' prior knowledge or experience related to the science topic or concept	3.45	4.38	10.4 (83)	<.001
Encourage students to explain concepts to one another	3.68	4.58	9.65 (83)	<.001
Use open-ended questions to stimulate whole class discussion (most students participate)	3.59	4.45	9.41 (82)	<.001

For the single-time survey respondents, teachers indicated they most often had students work in groups, encourage students to explain concepts to one another, and discuss students' prior knowledge about science topics/concepts. Interestingly, the one item where teachers showed significantly higher scores on the single-time survey (discussing students' prior knowledge), was one of the areas where teachers showed significant growth from pretest to posttest. It's likely that pretest-posttest teachers showed significant growth on this item between the two surveys because they spent a good portion of the EYM sessions discussing the importance of integrating this into their classroom practice while single-time survey teachers came to understand the importance of this classroom practice organically over the course of implementing the NGSS during the school year.

Table 11. Teacher Activities - Single-Administration

	Single-time mean	Pretest mean	*t*-test (df)	p-value
Have students work with each other in small groups	4.04	3.85	1.16 (42.44)	0.26
Encourage students to explain concepts to one another	4.04	3.71	1.92 (38.68)	.063
Discuss students' prior knowledge or experience related to the science topic or concept	3.96	3.52	2.75 (40.33)	.009

Confidence.

Finally, teachers responded to a selection of items from the Science Teacher Efficacy Belief Instrument (STEBI) that measured their confidence. Teachers' ratings increased significantly from pretest to posttest when looking at confidence as a composite score as well as for six of the eight individual items included in the composite score (see Table 12).

Table 12. Teacher Confidence - Pretest-Posttest

	Pretest mean	Posttest mean	*t*-test (df)	p-value
Overall Confidence Composite Score	3.51	3.87	6.39 (81)	<.001
Even when I try very hard, I don't teach science as well as I do most subjects.*	3.18	3.48	3.53 (78)	0.001
I know the steps necessary to teach science concepts effectively.	3.28	4.09	7.39 (78)	<.001
I understand science concepts well enough to be effective in teaching elementary science.	3.47	4.07	4.79 (80)	<.001
Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	3.95	4.16	1.71 (81)	0.09
I find it difficult to explain to students why science experiments work.*	3.58	3.54	0.29 (77)	0.78
I am typically able to answer students' science questions.	3.77	4.01	2.42 (80)	0.02
I wonder if I have the necessary skills to teach science.*	3.24	3.57	3.01 (78)	0.003
When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.*	3.73	3.96	3.81 (81)	<.001

*Item was reverse-coded

Overall, teachers indicated their confidence increased most in the areas related to knowing the steps necessary to teach science concepts effectively, understanding concepts well enough to be effective in teaching elementary science, and knowing how to help students better understand difficult concepts. Teachers' responses indicated no statistically significant differences in the areas of relating student science achievement to teacher effectiveness or teachers' ability to explain to students why science experiments work.

On the one-time surveys, teachers reported their highest scores on being able to help students' understanding when they had trouble with difficult concepts. Teachers also indicated they felt most confident in their understanding of science concepts in teaching elementary science along with knowing the steps necessary to teach science concepts effectively. Overall, teachers on the single-time survey had a higher mean composite score compared to teachers on the pretest, though not statistically significantly different. The one item where teachers did have statistically significant different responses was related to knowing steps necessary to teach science concepts effectively. Single-time survey respondents indicated they felt more confident in this ability than teachers on the pretest. For the remaining items, though, teachers' responses were similar across survey administrations, indicating similar feelings of confidence among the two groups.

Table 13. Teacher Confidence - Single-Administration

	Single-time mean	Pretest mean	*t*-test (df)	p-value
Overall Confidence Composite Score	3.71	3.51	1.27 (39.17)	.212
Even when I try very hard, I don't teach science as well as I do most subjects.*	3.13	3.18	.081 (32.3)	.936
I know the steps necessary to teach science concepts effectively.	3.88	3.28	2.43 (40.26)	.020
I understand science concepts well enough to be effective in teaching elementary science.	3.88	3.47	1.58 (42.24)	.123
Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	3.69	3.95	1.28 (34.45)	.210
I find it difficult to explain to students why science experiments work.*	3.83	3.58	1.29 (33.75)	.207
I am typically able to answer students' science questions.	3.85	3.77	.481 (42.75)	.633

I wonder if I have the necessary skills to teach science.*	3.50	3.24	.965 (40.22)	.340
When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.*	3.92	3.73	1.17 (38.80)	.251

Interview Results

Interview responses corresponded to five general themes. Confidence and comfort level around teaching science; scientific modeling; classroom practice/changes to classroom practice; general thoughts on elementary science; and specifics related to Engaging Young Minds. The sections below will detail teachers' responses related to each of these themes.

Confidence and comfort level around teaching science.

As research has shown, the majority of elementary teachers are not comfortable teaching science nor feel confident in their science teaching in the classroom. Therefore, one of the main areas of focus for the interviews was investigating respondents' general comfort level teaching science and the effect, if any, participating in EYM had on their confidence.

Interestingly, interview respondents did not align with the "typical" elementary teacher described in the research. Rather, they fell into two groups: those who stated they felt more confident in their science teaching abilities following their participation in EYM and those who indicated their confidence was not impacted by EYM because it was high to begin with. Teachers who participated in interviews demonstrated higher levels of both comfort and confidence in teaching science to their students compared to the general teaching population and the overall survey population. This may be due in part to the fact that all teachers who participated in interviews had more years of classroom teaching experience compared to the general teaching population. Teachers who participated in the interviews had an average of over

17 years of experience in the classroom, compared to the overall average of 14 (Walker, 2018[3]). This may also be due to the fact that teachers self-selected into EYM and then self-selected again to participate in interviews, and it would be surprising for teachers who felt completely not confident to volunteer to be interviewed.

When asked how participating in Engaging Young Minds impacted their confidence around teaching science, one teacher, Evelyn, stated "I can't say that it impacted my confidence, I think it impacted my interest and excitement about going back to do it. I cannot say that I gained confidence in it."

Some of the teachers indicated that participating in EYM did impact their confidence "to a certain degree," including Faith. Faith expanded and said that her confidence was "mainly impacted by being able to do some practice lessons or just see how other teachers would teach…" Jane stated that she "[g]ained confidence by incorporating the idea of starting with a phenomenon" into her classroom practice along with integrating a new style of questioning throughout content areas in her classroom. Additionally, Anita said, "At first, it was very intimidating, just because in general I think science intimidates a lot of teachers", indicating that the intimidation around the prospect of implementing NGSS, and specifically scientific modeling, decreased as EYM progressed and confidence necessarily increased. Similarly, Mindy indicated that "[EYM has] actually given me a lot more confidence. And when we're given standards or something new to do, there's a lot of anxiety. But with EYM, being able to implement it at our own pace, and in chunks, I think that's definitely helped."

Alyssa discussed the benefit she derived from participating in EYM follow up sessions. As she said, "In my opinion those [follow up] institutes that I've attended have really developed

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[3] http://neatoday.org/2018/06/08/who-is-the-average-u-s-teacher/

my knowledge level and also helped me feel a lot more confident about presenting material to my students." Evelyn's experience was the opposite, where she did not experience the benefit of consistent follow up, through EYM and her school. She felt that would have been a critical component to increasing her confidence: "I think also just gaining confidence in [my]self and being able to teach [these]skills, but I don't think there was a good follow through from the school either with where they are going next with it, with this information."

Teachers indicated greater comfortability, a component separate from confidence, in the interviews. Specifically, comfortability is a critical part of the foundation that leads to teacher confidence. When asked about how comfortable they felt teaching science, nearly every teacher indicated they feel comfortable when teaching science to their students. For example, Sam said "[I feel p]retty comfortable." While Evelyn stated, "I would say medium comfortable." Anita shared, "I feel pretty comfortable, because I really, honestly, I go over the lessons a lot," indicating that she reviews the lessons several times before she teaches them to her students.

Alyssa attributed feeling comfortable to extensive training she has sought out on her own for teaching science: "I'm pretty comfortable with teaching science. … there's a disclaimer to that. That is because two years into my teaching, I really sought out training. I've had 14 years where I've immersed myself in science, but when I first started teaching, I was very much afraid if [science]. I never saw myself as a scientist, so that's like my disclaimer. I'm comfortable now…" Miriam also acknowledged that this comfortability was not present from the beginning for her. Rather, now she "[feels] comfortable teaching science. It took me a long time to get here. Because I didn't really understand for many years, I think that what they were expecting science to be was very undefined and it was very confusing. And it wasn't what it is now, which driven by NGSS and driven by standards."

Similarly, Jane acknowledged that with the shift to NGSS, her comfort level, which is typically high, has been affected. “At this point, I'm fairly comfortable except we're kind of in a transition mode right now.” Mindy agreed, stating, “I'm fairly comfortable. Especially at a second-grade level. With the new standards coming through and the environmental aspect of it, I'm not as comfortable because it's not something I learned in school. So, there's definitely a learning curve there.” As Mindy referenced, some content areas have shifted to different grade levels with the implementation of the NGSS and for teachers who have taught the same grade level for many years, this can be somewhat of a difficult transition.

Faith, specifically, stated, “I would say I'm pretty comfortable teaching science. I feel like if I had had more say in the way it was designed, maybe I would have had more ownership over it and felt a little more comfortable.”

Michael and Alyssa both discussed feeling comfortable, but not necessarily confident in their science teaching. As Michael said, “I'd say out of all the other subjects, science is probably ... That comfortability is a little deceiving. … Science and math came naturally to me… whether that's my best topic to teach, I don't know.” Alyssa said, similarly, “I do have those times where I question like ‘oh man, do I even understand what I'm teaching?’ But, overall I feel comfortable doing it. I get excited about teaching science.”

Scientific modeling.

During the interviews, teachers were asked to describe how their understanding of scientific modeling changed after participating in EYM and how they incorporated scientific modeling into their teaching. Additionally, when teachers were able to do so, they were asked to provide an example of a lesson or unit in which they implemented scientific modeling and finally, if they noticed a difference in students' understanding of the material when scientific modeling was used compared to prior years when it was not.

Interestingly, some teachers struggled initially in the interviews when asked to describe how their understanding of scientific modeling changed. Several teachers required me to clarify what I was referring to when I used the phrase scientific modeling. Miriam asked "Can you explain to me what you mean about changing the model? What do you mean? … Okay, so using graphical organizers and that kind of stuff? Is that what you're talking about?"

When comparing these statements in the interviews to the results on the posttest, which teachers had completed approximately a year before the interviews, it's clear that teachers learned a great deal about scientific modeling during the week of EYM. However, the retention of the definition, and teachers' ways of thinking about modeling, shifted somewhat during the course of the year.

For some teachers, however, scientific modeling was easier for them to talk about and reference as something they implemented in their classrooms. For example, Mindy discussed a particular lesson where students had to design cars.

> "… they were able to design a car to go down a ramp and past, I guess it's like four feet, but we used the tiles on our floor to measure. Those were what they had to do. And then they had materials, and they were able to go through the whole engineering process with the team. And they were given two more times where they were able to revise their model, and then we would all race it. And so I think being able to go through the engineering process multiple times, and be able to revise it, and talk about why they went and decided to make that revision, I think that was very beneficial to the kids."

Michael also referenced a specific content area – electricity – where his students engaged in scientific modeling and benefitted from the chance to revise their thinking and initial models based on evidence. “I just remember, the oddest thing to me was that for none of the students in that particular group, batteries never came into play. So we spent probably three weeks investigating. … what was interesting was they came up with an idea which was tough to beat, which was just that the electricity comes from humans.” He went on to describe how, over the course of five weeks, his students finally had the “ah-ha moment … We were building circuits on tables with batteries, and then they just started trying to light them with themselves, and connecting things … then one kid just goes ‘You know, there's a battery inside of that thing. Can we just open it up and look at it?’ He was like, ‘There's a battery in there. There's gotta be a battery in there. It's gotta be a battery in there, which is connected to a circuit.’” Following this experience, he recognized that his students began incorporating the idea of circuits and electricity into other projects. Michael observed, “So I realized that whether or not the modeling is going to help them on a test, I don't know, what it did do, was help them with a lot of life skills, and the way they saw the world around them. So they started to become little engineers. That's what I'll say. They started using that content they knew had other world applications.”

Time.

A common sub-theme that several teachers discussed was how incorporating scientific modeling into their instruction affected the time it took to cover lessons. On the one hand, as Michael stated, “… modeling saves time, sometimes, in instruction, because you realize certain students have a grip of information that you don't even need to cover anymore. Then you can just chart it on the board and go, you know what, let's go with that, and we'll see if anything changes. You already know, well they got that part. Now I can move forward.”

However, Michael also acknowledged, and several other teachers stated similarly, when committing to incorporating scientific modeling in the classroom, it can also significantly increase the time spent on certain topics or lessons. He said, “I have a choice, I can give them the answer, or we could pursue this topic down the railroad tracks they're on, and I need to figure out a way to get them back to the tracks. That's a different way of approaching it. Then yes, [using scientific modeling] take a lot more time.” Jane stated, “Because it's more hands on and more observation, it did take a little bit longer just because of the nature of watching things go through their life cycle. We didn't tell them what it was at first, what kind of bug it was, so there was a lot more … theorizing or what could this be, what's going to happen next, that kind of thing. I think that they get deeper understanding than just a general idea.”

Alyssa also agreed, saying: “Typically, those would be like one-day type of lessons. It's like okay we sorted the planets and we had conversations about them. But, when I shifted to the kids asking questions and ... giving them experiences but they were the one trying to figure out and make meaning of what's happening. ‘Why there are patterns in the sky? Why do we see day and night?’ Those types of things. That really stretched things out a lot more. Typically, in the past that would be like maybe a two-day lesson. … With that modeling … I do have to say that lessons that I was normally typically covering in a shorter amount of time took me much longer.”

Classroom practice.

In general, teachers indicated during their interviews that they were more likely to incorporate science into their classroom and were less afraid to incorporate science into their lesson plans. However, for the majority, they did not necessarily change their classroom practices related to teaching science. Only one teacher, Sam, referenced implementing new classroom practices where he took pictures of student work so his class could see students’ thinking progression and changes over time. “I kept all the pre-designs and took some pictures of those designs so that we could look back and see how close the predictions were to the successful structures.”

Several teachers talked about how the concepts in the NGSS seemed to be what they were already doing in their classrooms, but now with different or new language tied to them. For example, Miranda said (emphasis added), “I think I have a better understanding on what is NGSS and what that looks like in the classroom. And especially with engineering, because engineering was just not a big part of science before. *Even though we were using it, but we weren't calling it engineering and the engineering standards*. So that's been a big shift also in science for me.” Miriam stated, when talking about the phenomena aspect of scientific modeling, “Looking at a piece of information, you know what I mean? And exploring that idea without giving the kids the answer. I don't know what you call that but ... I'm very bad at all the language of education. … Everybody wants to do this whole thing with semantics and I understand what modeling is, I understand teaching your kids on model, I get that.”

One teacher, Miriam, talked about the fact that they did not see a major shift in their actual classroom practice and the activities they implemented or their teaching style, but what did change was their expectation. As Miriam said, “…I think for me as a teacher, my expectation changed. I don't think it's my style of teaching changed. I think it was my expectation changed about what it was I was presenting.” She went on to say “… my expectation changed after I went [to EYM], because I saw that there was a different way to present the material. And I think that's mostly what affected the outcome for my kids.”

Multiple teachers talked about the main difference they saw in their classrooms – across content areas – was the change or increase in student talking and questioning. Namely, teachers found themselves were speaking less, and students speaking more. As Michael stated, "… the biggest thing is that I really don't have much to say anymore." Mindy agreed, saying, "… every time we did even math just with the common core math, I asked the question why. And then even in reading when they answer something, I always go back, and I want them to answer why. Or go back into the text and find where you found the answer." In other words, Mindy found her students to driving more of the classroom discussion, specifically around why they believed their answers to be true or what was the evidence for them.

Alyssa referenced a specific example of a science-related conversation she witnessed her students having outside the classroom on a field trip: "… [T]hey would just talk about it very naturally. We went on a field trip somewhere and it had nothing to do with science … One of the kids were looking out the window … It was so natural to have conversations about science. They're sitting on a bus having this conversation in a big rain, or whatever it was. But, they were commenting on it. I can't remember specific details, but I do remember the scientific conversation taking place about the world in a very casual way. Where that kind of tells me they're thinking about it, but it's not forced. It's now become part of just their experience. They go outside, they're asking questions about their world. That's where there was a little bit of the shift this year from previous years."

Integrating content.

Nearly every teacher also referenced the idea of integrating content areas or carrying techniques from their science teaching into other subjects. Across the United States, elementary school teachers generally are responsible for teaching all of the subjects to their students, except for "special subjects" such as music or art, if the school offers them. A surprising finding that stood out in these interviews is the idea that due to the fact that science integrates mathematics and language arts effortlessly, it may be a good idea to center science in the elementary classroom. Not only does science content lend itself to other subjects easily, the practice of scientific modeling can be translated to every single subject the teacher teachers in their classrooms. Namely, using the idea that students can take their initial knowledge, collect data, and reevaluate and change their thinking based on the data they collect is not and should not be exclusive to science.

For example, Michael talked about how in his classroom, "…[w]e kind of pushed the envelope in our classroom this year, and probably skipped some of the other subjects we should've done, but they tend to have access to learn all sorts of other content, when they're really engaged in doing that kind of science learning. That's one thing I did notice. I mean, even to the point of becoming better artists." Anita echoed this and said, "If we could do language arts, teaching reading and writing through science and engineering, I think it'd be perfect, cause all the other subjects come into play." Mindy said specifically of plan the following year, "…my next step in all of this is to be able to incorporate math into science. … Also, we have to now look at how we're going to teach science next year with our new reading series. And in the reading series, there's the science is supposedly embedded. There's some literature with the science…"

Alyssa discussed the idea of integrating content as an alternative response to the intense focus there has been on mathematics and language arts in schools in the US. "I remember that having guest speakers [at EYM] was always really valuable because it affirmed and it kind of solidified the need for science and that it's not unreasonable to say at a school, 'No, science is just as important as literacy and other areas and math. It kind of goes hand-in-hand.'" Miriam recalled one specific lesson where she integrated math and science in her classroom. To teach her students about potential and kinetic energy, they would build cars from pasta, which they had to "buy" from Miriam. Prior to building the cars, "I had to teach them what budgeting was, you know each piece of pasta cost a certain amount of money. So, then they had to figure out the cost of the car before it was ever even built. And we talked about industries and how industries have to do that, and how they have to figure out the cost and sometimes things are prohibitive …"

Miranda and Anita stated that implementing NGSS and increasing student talk in the classroom around science is particularly helpful with English Language Learner (EL) students. As Miranda said, "… because [a lot of] students are English language learners, they're developing their language for using science preferably to develop language, academic language, and then academic concepts." Anita agreed, saying that science is "… so good for EL students. There's so much language … I love it. I like when the kids work together and they're problem-solving and they're talking and they're trying and re-doing. I like that. That's reality."

Michael and Miriam also talked about how NGSS brings a sense of experiencing science as it is in the real world. Miriam referenced this in relation to integrating the process of doing science into all subjects: "[T]he reality is that science is science. It's the world that you live around, it's figuring out why things work the way they do and across curriculum, you can use those techniques." Michael spoke about the NGSS framework and how it helped him think about how he could apply science to other subjects in his classroom:

> "This is what NGSS, and the framework was about, was these things aren't compartmentalized. They do work together. Now, as a teacher, I go 'this is interesting' because we compartmentalize every topic and subject I guess, for many years, which was interesting because I thought, well how in the world do you teach 11 subjects in elementary school. … seeing real life, world application of science, and doing an investigation, and then

realizing, wait a minute, there is no such thing as just pure physical science. I mean it's incorporating with all the other science domains. There's always some other connection. There's always a cross cutting concept with the rest of the world."

General thoughts on science in elementary classrooms.

During the interviews, teachers shared thoughts related to science in general at the elementary school level, not necessarily specifically related to their experiences at EYM. As discussed in the literature review, the majority of elementary teachers do not have a substantial amount of training related to teaching science. As Mindy acknowledged, "…I think for the most part, most teachers are hesitant [to teach science]. It's a challenge, because you really only take in college one course on how to teach science, and we take an abundance of courses on how to teach language arts, how to teach reading, how to teach math. So, I think more emphasis does need to be placed on the science too."

Otherwise, teachers shared similar thoughts related to two topics – the importance of continued support when implementing NGSS and the difficulties their students experience with more inquiry-based teaching methods.

Nearly all of the teachers, regardless of grade level or type of school at which they taught, mentioned how difficult it is to implement new, inquiry-based techniques in the classroom namely because students are so concerned with getting the right answer the first time. As Evelyn said, "it can be hard because they often just want the answer; I even have one girl who's one of the brightest girls in my class, but she hated ever guessing about how something might happen, because she didn't want to guess wrong." Jane agreed, saying "Some of my kids, they don't like to be wrong" and Alyssa said, "They wanted to know the answers."

Mindy indicated that the most difficult part for her students was having to cope with the feelings when they revised their process based on data from the first attempt and the revised attempt was worse than the original. “I noticed a lot of kids, they feel bad that okay, we did a worse job. Just because we have a lot of kids who think about their grade, ‘now we're going to get a bad grade’.” She went on to say that having her students journal about their thought process was also cause for anxiety about grades: “… my kids always had a very difficult time, or they waited to see what the right answer was. … [T]his year I prefaced it with, okay, there's no right or wrong answer for this. You’re just giving me your thoughts. I just want to know what you were thinking. And your thought, that's what I'm grading you on. I don't care how far the car went. I'm gonna grade you on your thoughts. And so it made them look at it in a completely different light.” She said that some of her students struggled with this concept and four of them simply could not accept that they were only going to be graded on their thought process.

Similarly, two teachers specifically referenced the new California Science Test (CAST) in their interviews, which is the new, NGSS-aligned online assessment that students take once in fifth grade, once in eighth grade, and once during high school (either in tenth, eleventh, or twelfth grade). These teachers recognized that they, and their students, are constantly aware of the impending test and the importance of their test scores. Anita stated that she wants her students “to be able to be comfortable with [science] and understand, because I know in fifth grade, they're gonna have that science test,” referring to the new California Science Test, which was developed alongside the implementation of the NGSS. Michael also explicitly acknowledged how pervasive testing affects both students and teachers: “We've removed that portion of education, which is driven by curiosity, not by wanting to do well on a test.”

Teachers also discussed the difficulties that come with trying to implement something like the NGSS without intense, continued buy-in and support from their individual schools/principals and the district as a whole. As Evelyn stated, “I took lots of notes and I typed up all the notes and I sent it to the principal, which is the head of the school, and I got really no response which was frustrating, because I thought it was really interesting.”

Similarly, Mindy said, “I thought it was so wonderful and great, but it wasn't something that ... everyone has to buy into it at your school to be able to do it. And it wasn't something that everyone bought into here. I'm sure I can do it at a smaller level, but time constraints, I have to pick and choose what I want to be able to do with my students.”

Sam addressed the way different priorities across the district affected his ability to implement ideas from EYM in his classroom. “… there were so many other demands and new initiatives and mandates and other things to cover … We were all wrapped up and ready to go after EYM, but the focus and ambition really got jeopardized by everything else that was due or past due or things that should be changed. It just seemed like there was one initiative after another and one program after another.” Anita also talked about how it would be difficult, or impossible, to try to collaborate with teachers who had not participated in EYM due to the significant differences in knowledge about NGSS across the district and state. As Anita said, “I have a lot of friends who are teachers outside of LAUSD and they have never heard of NGSS at all. … they started Googling it, cause their district has not told them anything … They were shocked. I feel like we're behind. I can't even imagine how they must feel, because we have a couple trainings through the district.” Alyssa had a similar experience within her own school. “There was a third-grade teacher who admitted that her team doesn't even teach science. So, it was kind of like I can't even believe that. But I can believe it because I could see it. I could see the lack of science. Even if they didn't have the content, they would at least come in with scientific practices already in place. Maybe it wasn't explicit, but because teachers fostered at least that critical thinking and some of those other skills. It was just kind of natural. But, definitely by far I didn't see the kids come in with that level of thinking…"

Additionally, several teachers mentioned how they did not have the needed financial support from their schools or the district. Consequently, at least some of the cost of materials for science was something they personally had to shoulder and when they couldn't, it led to them being unable to do everything they wanted in their classrooms. As Mindy stated regarding equipment, "… We genuinely wouldn't have the microscope or the technology at an elementary school level to do so."

Miriam had a similar experience, saying, "I work for LAUSD, so the whole thing is that LAUSD doesn't really want to spend any more money. And LAUSD being LAUSD, "Oh, just use what's at your school site." … And so, a lot of this stuff that was happening, [at the follow-up sessions] they would say, 'Oh, just pull from this box, pull from that box.' And I said, 'I don't have those boxes.' … I'm playing on my ear, topical fix for everything. It was ridiculous." Miriam stated succinctly: "But that's the nature of education, I think. That's what always happens. You're expected to go out and purchase all that stuff."

General & EYM-specific professional development feedback.

During the interviews, teachers provided feedback on EYM both specific to the session as well as professional development in general. Teachers were asked to detail the parts of EYM they found most helpful or most affected their science teaching and, conversely, which parts of EYM were least helpful or least affected their science teaching.

In their responses, teachers identified several common elements of EYM that they found most helpful, including how inspirational they found the speakers and Kenneth (Ken) Wesson, in particular. Ken Wesson, a professional/keynote speaker, presented on the neuroscience of learning. He was referenced by name both in multiple posttest survey responses as well as by Sam during his interview: “Listening to Ken Wesson was just crazy. The guy is a rockstar by anybody's standards. Ken Wesson was phenomenal. He was very inspirational.” Miranda enjoyed “the presenters, I mean the presenters were knowledgeable. And they ... I learned a lot that day.” Similarly, Anita said, “I really, really enjoy the presenters. The presenters are awesome. And one of the things I do like about them is that they're open to critique.” Alyssa agreed, saying “The guest speakers always were inspiring. From that, it validated some of the things and affirmed some of the good practices that I think sometimes get lost from certain school sites. Having guest speakers was always really valuable because it affirmed and it kind of solidified the need for science…” Additionally, Mindy stated “I liked the speakers, because they always got me energized to get me confident that I can come back and be able to do it in my own classroom.” Clearly, teachers found the time spent listening to the guest speakers to be a valuable departure from lesson planning and the core content of EYM.

Teachers also agreed that being around other elementary teachers who were attending voluntarily and clearly wanted to be there led to a good learning environment. As Miranda observed, “I thought it was dynamic. I really enjoyed ... I loved the idea that these people were here because they wanted to be there. And everybody was engaged in science and loved learning about science. I loved it. It was great.” Evelyn agreed and expanded saying “I thought all of the teachers that they had there were just outstanding and had a lot of interesting information to share and ideas to think about.” Similarly, Jane said, “being around everyone was great, just the energy of everyone interested in science." Sam also liked how, in general, "we got to really be in the driver's seat and see how engaging science can be, especially when it's an open-ended pursuit."

Along those lines, teachers enjoyed being able to go through the process of discovery and be students to a certain degree themselves. As Miranda said, "I think it was very important that teachers were given an opportunity to go through this process of discovery." Evelyn agreed, saying "That's one way that I think is most helpful. It was a very hands-on kind, and I think, I had to step out of my comfort zone." Similarly, Faith appreciated "being a participant as if I were a student, [that] definitely helped." Part of the time was spent in whole group activities while a significant portion was spent in grade-level specific breakout groups, which teachers very much appreciated. Faith expanded on her previous statement, saying "Also, having time in our grade level teams, I think that was one of the biggest things. … the fact that we do break up into the upper elementary and then the lower elementary. I think that's the other thing that's really helpful." Miriam enjoyed that "the pull-out sessions were actually taught by teachers themselves, so they knew what some of the issues were. And if they didn't have the answer, they just said, "We don't have the answer. Maybe you guys have some feedback for us." And I just really liked the feeling of the whole thing. I just thought it was a really well done."

Michael also benefitted from participating like a student: "The important connection is that it's not just you, it's the child in you. This what you want to do to your students. You want them to have this experience, so that they are inquiring about stuff. *I think if I had not have had that feeling, I wouldn't have gone and taken the risks that I did this year*." (Emphasis was added to the previous statement.) Alyssa explicitly found the opportunity to think like a student the most helpful. She said, "The other thing that has really been beneficial has been the going through a model lesson as well. Going through the lesson as the learner. It wasn't necessarily the idea that I would mimic the same lesson, but the thinking behind a lesson is what I was able to take with me." This resonated with Mindy as well. She found the most helpful part "being able to sit there and struggle to go through that activity. I think is very beneficial. … And then I loved the breakout sessions, so that we could actually do the activities, struggle through it, and then be able to see what the activity is supposed to look like, or the engineering process is supposed to look like."

The portion of EYM teachers found least helpful was the nanoscience content. During their interviews, eight of the ten teachers talked about how the nanoscience content was inappropriate for the developmental level of their students and they didn't know how to scale it down for them. As Evelyn said, "I thought it was fascinating, but I didn't really understand it. It was mostly the stuff towards the end that was more of the nano science…" Alyssa agreed, saying "I had a hard time connecting that particular [nanoscience] lesson to my standards." Mindy acknowledged that she would have liked to implement the nanoscience content in her classroom, but she wasn't sure how to do so. "The nano science, it's not quite something a second grader can do. I'm sure if I paired them up, maybe with a fourth or fifth grader, we might be able to do it, but it wasn't something that I've been able to do yet. Because we have the kits to do so, I would love to be able to do it, I just haven't figured out a way to do that." Miriam also struggled with the nanoscience content: "I didn't have any money and I didn't have the ability to really know what I was doing, and no one was supporting me, so it was a very hard … I couldn't really implement all the stuff that I learned about nanotechnology and all that stuff, and honestly some of it was pretty lofty for me."

More generally, through some teacher's comments, it was clear that it is not sufficient to call a professional development appropriate for "elementary" level. Rather, it needs to be divided into upper elementary and lower elementary. This is likely why teachers enjoyed the portion of the session spent in their grade-level breakout groups so much – these breakout groups were specifically catered to the level at which teachers were teaching.

As a specific example of why it is important to differentiate between upper and lower elementary, it's very difficult for teachers of lower grades (i.e., kindergarten through second grade) to adapt writing-heavy curriculum for their students. In these lower elementary grades, students do scientific modeling without the ability to write like upper elementary students and therefore it looks different from modeling in grades where students have more experience and ability to write. As Faith said in her interview, "… [during EYM] we wrote geologic stories, so based on what we saw, we learned about the different names for the different shapes and art elements in the pictures that we saw, and then we were supposed to translate it into our own little story [and with first graders] most of them are not really writing that much just on their own, even for fun. … so, for them to do something like that is not really feasible at all." Michael also acknowledged that often in professional development sessions, "every teacher wants to have everything done at their grade level… which is sort of impossible … there's a sense that I enjoyed it, but it doesn't apply to my grade."

Summary

The data collection and analysis revealed that teachers very much enjoyed EYM and increased student-led discussions in their classrooms following participation in summer 2016, but few changes were made specifically related to integrating scientific modeling. Table X, below, provides a brief summary of the answers to each of the research questions.

Table 14. Summary of Answers to Research Questions

Research Question	Summary of Results
1. What do teachers report as changes to their science teaching following participation in EYM? 1a. Specifically, what changes do teachers report related to their use of scientific modeling?	- Teachers reported significant increases in **expected** changes to classroom practice on surveys - Teachers reported they were more likely to teach science, but revealed minimal changes to **actual** classroom practice in interviews - Most significant change was increase in student discussion, talk, and questioning - Surprisingly, varied understanding and implementation of scientific modeling
2. To what extent is teacher confidence/self-efficacy related to teaching science changed by participating in EYM?	- Teachers demonstrated significant increases in their confidence on pretest-posttest surveys - Teachers who completed the single-administration survey showed similar results to the pretest answers - indicating in general, participating in EYM does not increase confidence permanently - In interviews, teachers indicated they started with higher confidence to begin with - Participating in EYM had more of an effect on teachers' comfort around teaching science than confidence
3. How do students respond to using scientific modeling to understand science content? 3a. In what ways is student use of modeling different from how they typically gain understanding of science content?	- Minimal implementation of scientific modeling = minimal information about this question - Some teachers did report carrying over some techniques such as increasing student talk to all content areas - One area teachers noticed students struggled with was not knowing the right answer or the right technique from the beginning (crucial for students to be able to do this to do modeling well) - Teachers did note lessons where they attempted modeling took much more time than previous years, but students **seemed** to retain content better

Chapter 5 – Discussion of Results

Introduction

Science instruction has seen a recent newly invigorated focus in the United States, especially in elementary classrooms, due in part to the implementation of the Next Generation Science Standards. The standards introduce a new way of teaching science in addition to different or new content and were developed partially in response to the consistent underperforming of students on measures of science achievement (OECD, 2014; US Department of Education, 2015). Teachers (especially elementary teachers) are notoriously less confident in their science-teaching abilities compared to other topic areas (Adams, Miller, Saul, and Pegg, 2014; Amato, 2004; Dorph, et al., 2011; Fulp, 2002) and the NGSS brought a significant change to what was required of teachers, sparking even more unease. One of the ways to address teachers' low confidence, along with their lack of content knowledge, is to for teachers to participate in professional development. One such professional development which was offered to teachers was Engaging Young Minds, a partnership between the Science Project at UCLA's Center X and LAUSD.

This project was originally inspired by three factors: my interest in the NGSS, my interest in studying teacher professional development, and the overall context of science (or lack thereof) in the elementary classroom and the implications therein. I wanted to determine what effects Engaging Young Minds could potentially have on participants and see how effective the structure was at affecting teachers' classroom practice.

I chose to use a mixed methods design because I believe oftentimes, mixed methods are the best way to uncover the most information to help answer the question, especially in education research. I used surveys in order to look at the typical experience teachers had during EYM and to be able to quantify teachers' feelings of preparedness and confidence as well as see their predicted classroom practice. However, a survey would not have been sufficient to truly understand how teachers were impacted by participating in EYM, so the interviews were designed to uncover more details. Later in this chapter I will discuss how I would have conducted this study in a perfect world, specifically additional methods I would have used.

In my surveys, I investigated teachers' feelings of preparedness to teach general science topic areas as well as just the subject of science overall. As prior research has shown, and continues to show over the years, elementary teachers, particularly lower elementary teachers, are woefully underprepared in science content knowledge and pedagogy (Banilower, et al,, 2013; Banilower, et al., 2018, Feistritzer, 2011). I wanted to see if teachers felt their formal education prepared them differently to teach science compared to EYM, especially given that credential programs typically require very little science content courses compared to math.

I also wanted to see how familiar teachers were with the eight NGSS Practices, and especially Practice 2 (Scientific Modeling) given that my study occurred in the middle of the NGSS transition phase for LAUSD schools and teachers should have been relatively familiar with the NGSS by that point (see Appendix A). I provided teachers an opportunity to write about scientific modeling in their own words to see how their definitions changed during the course of the week. I also was curious to see what kinds of classroom practices and activities teachers were typically using and how they predicted those would shift as they participated in EYM. Finally, I wanted to measure teachers' confidence and see how it was affected by EYM given that we know that for elementary teachers, confidence around teaching science is notoriously low.

The data analysis revealed several key findings. First, the implementation of the NGSS and its incorporation into elementary classrooms, at least in LAUSD, was not given a long enough timeline. While the Common Core State Standards was a large shift in the way mathematics is taught, there is little precedent set for such a change in science. Consequently, there is virtually no research to cite related to best practices when implementing such a dramatic policy and classroom practice change in science. In my data collection, teachers did not reveal much outside influence that was motivating them to implement the NGSS, aside from the new California Science Test. While this was not necessarily representative of every teacher or district across the state, given how large LAUSD is, this still represents the experience for a significant portion.

Second, elementary teachers discussed several interesting ideas for changes to the structure of the elementary classroom but the most ubiquitous, with the biggest implications, is the idea of integrating content with science at the center of most lessons.

Finally, EYM is a well-designed, respected, and well-loved professional development, and it did shift teachers' feelings of confidence along with their knowledge about specific topic areas, but it does not have as large of an impact on teacher classroom practice as predicted.

This section will discuss each of these findings as well as some implications of them. I will also discuss limitations of this study and provide suggestions for future research as well as my overall thoughts.

Discussion of Results

For Research Question 1, I was interested in learning what teachers reported as actual changes to their classroom practice in general following participation in EYM as well as specifically related to scientific modeling. While teachers predicted significant changes in their classroom practice on the posttest survey at the end of the summer 2016 session, they reported minimal change to actual classroom practice during the subsequent 2016-2017 school year.

Namely, teachers reported an increase in student talk, student questioning, and student-led discussions in their classrooms, but minimal (if any) changes to classroom practice related to scientific modeling. Additionally, it was particularly surprising how several teachers struggled to understand what I was referring to when I asked about scientific modeling in the end-of-year interviews. Given the significant shift in teachers' open-ended survey responses with their definitions of scientific modeling on the posttest surveys, I expected that teachers would have been able to talk more about scientific modeling. Instead, some needed a reminder of the definition and were not able to talk at all about what this looked like in their classrooms.

Research Question 2 was designed to assess the impact on teachers' self-efficacy following participation in EYM. While surveys demonstrated significant growth from pretest to posttest in this area, teachers who completed the single-administration survey scored more closely to teachers' pretest answers. This indicates that while EYM does impact teachers' confidence to a certain degree, that effect is not sustained over the long-term. Furthermore, teachers who participated in the end-of-year interviews typically had much higher confidence to begin with, and it was not necessarily impacted one way or the other by participating in EYM.

Finally, Research Question 3 investigated how teachers implemented scientific modeling in their classrooms, and the impact it seemed to have on their students. Unfortunately, most teachers were not able to speak in interviews to this very much given that most did not implement scientific modeling in their classrooms during the school year. One thing which teachers did report implementing and carrying over across all of the content areas in their classrooms, was the increased student talk (as mentioned above). This seemed to carry over nicely to all lessons, regardless of content, in nearly every teacher's experience. One element teachers noted their students struggled with was the element of uncertainty, and being able to accept that they may not have had the right answer or process from the beginning. Given how difficult this was for teachers' students, it makes sense that they would want to build students' capacity in this regard before fully implementing scientific modeling since high-quality modeling requires students to be okay with not being correct on their first try every time. For those teachers who did implement modeling in some format, they noted that the lessons took significantly more time, but students did seem to retain content better.

Implications of Results

It is important to first acknowledge that I am not, and have never been, an elementary classroom teacher. Rather, I have experience as an education researcher and program evaluator and have spent significant time talking to and observing elementary teachers in their classrooms. I am forever in awe of the tenacity of elementary teachers. Their responsibilities are truly endless. Additionally, there is an interesting dynamic in education where, as Miriam stated in her interview, "It's the only profession in the world where people are not honored the older they get and the more they know. … it's so bizarre to me because it takes so long to learn how to teach well. And it's the only profession where they are standing there tapping their foot waiting for you to get out the door. Because you cost too much money, you're too old."

While I understand the context relatively well, I still do not know what the day-to-day is truly like for teachers and through the course of this project, I have come to gain an even deeper understanding of what is being asked of elementary teachers in the US. From my perspective, the incorporation of NGSS into classrooms – on top of the already demanding mathematics and ELA standards – leads to a set of requests and requirements which are nearly impossible to meet.

NGSS implementation timeline.

Bringing a renewed focus to science in elementary classrooms is both needed and a monumental task. Considering how few minutes have been spent teaching science at the elementary level for so long, this shift was obviously going to require multiple years and significant effort to achieve. As shown in studies by Blank, 2012; Griffith & Scharmann, 2008; and Perie, Baker, & Bobbitt, 1997, elementary teachers across the US were teaching, on average, two hours or less of science content per week. Though the new NGSS-aligned science tests do not begin until fifth grade, it is crucial that students, beginning in kindergarten, receive significant attention to science content to build the knowledge base necessary to do well on the tests. Consequently, teachers need to dedicate substantially more time to science in their classrooms and preparing teachers to do so takes a very long time.

Through the course of this project, especially since I had the benefit of observing changes over more time than I originally anticipated, it seems that the original implementation plan for NGSS was overly ambitious. (See California Department of Education, 2014). Gao, Adan, Lopes, and Lee (2018) investigated the early indicators of NGSS implementation in 2018 and at that time found that awareness and implementation of the standards varied widely across the state of California. Specifically, teachers in low-performing districts demonstrated much less awareness than teachers in all districts. Additionally, they found that only 60% of survey respondents indicated science was treated as a priority in their district, leading to potentially even more uneven awareness and implementation.

During the interviews I conducted, it was evident that teachers seemed more likely to include science instruction in their classrooms and felt more comfortable with the idea of teaching science than before participating in EYM. However, aside from increasing the amount of student-led conversations in their classrooms, there was very little evidence to suggest that teachers were changing their instructional practices and how they actually did science to accommodate for the proposed changes in NGSS.

Specifically related to EYM and the practice of scientific modeling, teachers were surprisingly unable to describe much in terms of implementing modeling in their classrooms during the school year. This was particularly interesting when looking at the responses on the posttest survey where the same teachers not only had clear, detailed descriptions of what scientific modeling is but also indicated they would likely implement scientific modeling in their classrooms during the school year. I assumed that because they left EYM with such a clear vision of the benefits of scientific modeling, along with the lessons discussed during the week, it would be relatively easy to translate it into their classrooms. What I did not anticipate was how much more support would be needed to truly integrate scientific modeling into teachers' classrooms. For example, as Miriam said, "I didn't have any money and I didn't have the ability to really know what I was doing and no one was supporting me, so it was a very hard … I couldn't really implement all the stuff that I learned about nanotechnology and all that stuff, and honestly some of it was pretty lofty for me."

Additionally, it was interesting that on the single time survey (where the vast majority of teachers had not participated in the 2016 EYM) they rated themselves moderately to highly familiar with Practice 2 (related to scientific modeling) yet were unable to, for the most part, give clear and accurate definitions about scientific modeling. This is further evidence that teachers were not as familiar with the NGSS as would be expected when taking into account the initial implementation plan.

When looking at the statewide implementation plan, the original plan spanned approximately five years from adoption of the new Standards in 2013 to implementing new assessments in the 2018-19 school year (California Department of Education, 2014). During the course of these five years, the plan included approximately three years of NGSS awareness/transition webinars and workshops, from April 2014 through June 2017. However, when I interviewed teachers in June and July of 2017, there was almost no evidence of the state and/or district devoting adequate time to this activity. Most teachers I interviewed indicated that outside of their participation in EYM, they had attended minimal or no additional science professional development either at their schools or through the district itself. Furthermore, one teacher explicitly talked about how her friend, who was a teacher in a district outside of LAUSD, had never heard of NGSS as of summer 2017. This is directly in line with prior research that showed a significant, and sometimes complete, dearth in science PD available to teachers (Dorph, 2011).

When you combine the lack of school and district support with the fact that the science tests begin only in 5th grade, there's a potential for the NGSS and science to still be de-prioritized due to the intensity and frequency of testing for math and ELA.

Integrating content and changing what the elementary classroom looks like.

One of the biggest unexpected themes I encountered during the course of interviews was the idea of integrating content and implementing NGSS-style teaching methods across all content areas in the elementary classroom. Several teachers said – implicitly and explicitly – that it seems like elementary classrooms in the US would benefit from actually centering science content since math, ELA, history, social studies, art, and technology can all be incorporated into science lessons – sometimes concurrently. This fits nicely with the vision of the NSTA (2014) to move from teaching science as a set of disconnected facts through lectures to truly embracing the idea of science as an interconnected body of knowledge.

Given that most elementary teachers do not have much, if any, formal training in how to teach science or take science content courses (Banilower, et al., 2018), and they feel less confident about teaching science (Neil, Murphy, & Beggs, 2007), it seems as though one answer might lie in the idea of having a graduated teaching model where each classroom has more than one teacher in it at a time. For example, there could be a veteran teacher, along with one or two new teachers, which would prevent one teacher from having to try to teach all subjects every single day. The current structure, wherein elementary teachers do teach every topic area, but in a separated, distinct section, is inefficient and ineffective. Or, there could be a teacher who has more training in math, one who has more training in science, and one who has more training in language arts. Subsequently, we would have elementary teachers were more "specialized", similar to secondary teachers, and they primarily attended professional development related to their content area, leading to an increased focus on teachers' areas of strength. Research has shown when professionals focus on building their existing strengths, and not trying to force growth in their areas of "weakness", their performance increases substantially (Ludema & Johnson, 2018).

This also relates to one of the things several teachers said in their interviews and on the posttest survey, which is that one of the reasons EYM was so enjoyable was that teachers clearly wanted to be there, and even if they didn't have a lot of science content knowledge, it didn't matter because the enthusiasm made up for it. If the teachers who chose to attend EYM, and were there because they already enjoy science more than other elementary teachers, were responsible for teaching only or primarily science in the elementary classroom, this could have a profound impact on how elementary students learn and experience science.

The main takeaways related to professional development in science for elementary teachers were that the length of time of EYM, while longer than many professional development sessions, was still not long enough. That is, four days during the summer and for follow-up days during the school year which were optional were insufficient to effect change in classroom practice. This was most evident through teachers not being consistently sure of what I was referencing when asking about scientific modeling and could not provide consistently good examples of this in their classrooms. However, it is not only the length of the professional development that matters. It also depends on the amount and quality of follow-up and support teachers receive once they're finished with the professional development and they are back in their classrooms. As with all education initiatives which are significant shifts from the status quo, we cannot expect teachers to learn about something in one session and be able to implement it well from that point on.

Furthermore, it was interesting that many teachers indicated both on the surveys and in interviews, that professional development cannot just be considered "elementary." Rather, there needs to be further differentiation for upper and lower elementary. For example, most K-2 teachers talked about how it was impossible to integrate the nanoscience content and some explicitly stated how difficult it was with the NGSS being very writing-heavy. Additionally, teachers found extremely helpful having multiple opportunities to meet in grade-level groups to practice lessons. This helped teachers see "how will this *actually* look in my classroom" as opposed to "well, this is how it was *designed* to go."

A successful professional development should provide as much opportunity for this type of experience as possible, especially for science. One of the ways teachers indicated that they increased their confidence was in the ability to be a true learner and go through the discovery process, grappling with new content, similar to how their students interact with science in their classrooms.

A final important element of an effective, engaging professional development is having inspiring presenters and speakers. For example, presenter Ken Wesson was referenced in multiple surveys and buy multiple teachers interviews due to his ability to engage participants.

Changes to my study and suggestions for future research.

If I were to conduct this study again, in a perfect world, I would change several things. First, I would have recruited teachers from schools that were more closely aligned to LAUSD averages. I believe this may have given me a more representative insight into elementary teachers in LAUSD. Second, I would add interview questions directly tied to specific classroom practices assessed on the survey. For example, I would ask teachers to provide examples and estimate how often their students were required to supply evidence to support a claim. I would also ask questions about the specific areas of confidence teachers rated on the survey such as their ability to answer students' science questions and how well they understand science concepts. Third, I would have conducted interviews twice – once at the start of the school year and once at the end in order to see how their responses changed during the course of the school year. Finally, I would have been more aggressive about either observing teachers in the classroom or requiring them to provide evidence of student modeling for us to discuss. Given how time-intensive observations are, I don't know how realistic it would be to do, but at least looking at student work would have been helpful. However, given how little teachers incorporated scientific modeling into their classroom practice, it wasn't really possible to look at student work in my study anyway.

For future research, I would suggest doing a comparison between the proposed NGSS implementation timeline and what is actually happening in teachers' classrooms. How are they really being incorporated into the curricula? What is the gap between ideal and real implementation? Further, I would investigate the relationship between science test scores and classroom practice. The 2018-19 school year was the first year the new science test was implemented in classrooms in California and as of this writing, results were not yet available. While standardized test scores are by no means a perfect measure of student knowledge, they are one way to gauge a baseline and determine areas where students need further instruction.

Concluding Thoughts

While the majority of my results support ideas already in the literature, the idea of integrating content is a significant shift in the conceptualization and practice of how elementary students are taught in the United States, but one that deserves significant thought and attention. Additionally, I am so curious to see the new California Science Test (CAST) results over the next several years as well as how the changes to science instruction potentially affect student performance in other content areas as well. I believe that education in general, but especially science, can be an equalizer, when taught well. We have an exciting opportunity to introduce this generation of students, and those in the future, to the benefits and fun of learning science. While test scores are important to a certain extent, I am most excited to see how students learn to think differently about what they see around them and eventually bring those thinking and analytical skills into the world to make even more discoveries which can benefit all.

Appendix A

This Appendix contains both the California state NGSS implementation timeline as well as the LAUSD-specific implementation timeline.

CSTA

CALIFORNIA'S ADVOCATE FOR HIGH QUALITY SCIENCE EDUCATION

California NGSS Estimated Implementation Timeline

2013 – 2016	**NGSS Awareness Phase** - represents an introduction to the CA NGSS, the initial planning of systems implementation, and establishment of collaborations.
September, 2014 – May, 2015	Framework committee works on revision of the ***Science Curriculum Framework***. Meeting Dates: September 9-10; October 9-10; November 5-6; January 22-23 and March 26-27; and May 20-21.
May, 2015	5th, 8th, and 10th graders take **existing CST/CMA/CAPA science test**.
August 28, 2015*	*PROPOSED*: IQC Science Subject Matter Committee (SMC) reviews draft ***Science Curriculum Framework***.
September 24-25, 2015*	*PROPOSED*: Draft ***Science Curriculum Framework*** approved by IQC for public review.
October 2 – 4, 2015	**CSTA Annual California Science Education Conference – Sacramento, CA**
October – November, 2015*	*PROPOSED*: First 60-day public review period of ***Science Curriculum Framework***.
January 31, 2016	Current deadline for SBE to approve curriculum ***Science Curriculum Framework*** per SB 300 (Hancock, 2013)
February, 2016	IQC Science SMC reviews results of public review of ***Science Curriculum Framework*** and makes edit recommendations.
2015-2018	**NGSS Transition Phase** – build foundational resources, implementing needs assessments, establishing new professional learning opportunities, and expand collaborations between all stakeholders.
March, 2016	Deadline for the SSPI to submit plan for science assessments not required by the Federal government.
May 19 - 20, 2016*	*PROPOSED*: IQC analyzes results of public review, revises draft, and approves second draft of ***Science Curriculum Framework*** for public review.
May, 2016	5th, 8th, and 10th graders take **existing CST/CMA/CAPA science test**.
June – July, 2016*	*PROPOSED*: Second 60-day public review period of ***Science Curriculum Framework***.
September 2016*	*PROPOSED*: SBE to take action on the proposed ***Science Curriculum Framework.***
2016 and beyond	**NGSS Implementation Phase** – expand professional learning support, fully align curriculum, instruction, and assessments, and effectively integrate these across the field.
2016-2017	Anticipated **Pilot Testing Year for NGSS Assessment**.
May, 2017	5th, 8th, and 10th graders take **existing CST/CMA/CAPA science test**.
2017 – 2018	Anticipated **Field Testing Year for NGSS Assessment**.
November 2018*	*PROPOSED*: **Instructional materials** adoption by SBE.
2018 - 2019	Anticipated Administration of **Operational NGSS Science Assessments**

This timeline was developed by the California Science Teachers Association (CSTA) using a variety of information sources. This timeline is an estimate, as many steps in the process do not have fixed timelines yet and the Awareness, Transition, and Implementation phases have some overlap. CSTA will update this timeline as information become available.
**These dates are not firm and will require action by the legislature and state board of education before they can be considered confirmed.*

Updated: January 28, 2015

NGSS Implementation Timeline*

School Year	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
State Assessments	CST Grades 5, 8, 10					
				NGSS Test Pilot for selected schools in California Grades 5, 8, 11**	NGSS Test (Field Test) Grades 5,8,11**	NGSS Test Grade 5,8,11**
Instructional Materials/ Textbooks	No new instructional material until 2018-2019 K-5: FOSS CA 2007 6-12: Materials from 2007 Textbook adoption					
						State Adoption
California NGSS Framework Development	April 2013- NGSS is published Sept 2013- California State Board of Education Adopts NGSS	California NGSS Framework in development	October/ November 2015-First Public Review of California NGSS Framework	June/July 2016- Second Public Review of California NGSS Framework California NGSS Framework available January 2017	Framework is in full implementation ⟹	
					Commit to course pathways model for middle and high school grades	
Student Readiness	Students in grades K, 3, and 6 will be assessed on NGSS when they are in grades 5, 8, and 11	Students in grades 1, 4, and 7 will be assessed on NGSS when they are in grades 5, 8, and 11	Students in grades 2, 5, and 8 will be assessed on NGSS when they are in grades 5, 8, and 11	Students in grades 3, 6, and 9 will be assessed on NGSS when they are in grades 5, 8, and 11	Students in grades 5, 8, and 11 will be assessed on NGSS Field Test	Students in grades 5, 8, and 11 will be assessed on NGSS
LAUSD Instructional Resources		Integrated Unit in Grade 4 and 5	NGSS Interim Assessment Option (secondary)		Instructional Guide for K-12 Available	
			Integrated Unit in Grade 3			

*This is the most current information as of May, 2015 based on state and LAUSD projections and reference resources from www.cde.ca.gov and www.cascience.org

** The grade levels are recommendations due to ESEA- Students must be assessed once in each of the following grade spans: grade 3-5, 6-8, 9-12. Each NGSS test is cumulative for the span years, e.g. Grade 11 test will assess the content for grades 9 through 12.

LAUSD Office of Curriculum, Instruction, and School Support (June, 2015)

Appendix B

This Appendix contains the pretest survey, the posttest survey, the single-administration survey, and the interview protocol.

Pretest Survey

You are being asked to complete this survey because you are a teacher in an elementary (kindergarten through sixth grade) classroom and you are currently or have participated in the Engaging Young Minds professional development. This survey investigates elementary teachers and their experiences with teaching science. Specifically, the survey will be used to investigate teachers' feelings of preparedness to teach science content (both generally and regarding grade level specific topics) as well as teachers' confidence around teaching science in their classrooms. You do not have to answer any question you do not feel comfortable answering and have the right to end the survey at any time.

Your answers will be kept confidential and will be used to inform my dissertation study. Please contact me, Nancy Hankel, with any questions or concerns via email (nhankel01@ucla.edu) or by telephone (520-440-9624).

Please provide the following information:
1. Name:
2. Grade level you are teaching during the 2016-17 school year:
3. Number of years full-time teaching (at any grade level; excluding student teaching):
4. Number of years full-time teaching at the K-6 level:
5. Please indicate the year(s) you participated in EYM (circle all that apply):

2012 2013 2014 2015 2016

Please rate the degree to which you disagree or agree with each of the following statements.

I feel that my education and teacher preparation program prepared me well to teach…	**Strongly Disagree**	**Disagree**	**Neither Disagree nor Agree**	**Agree**	**Strongly Agree**	**Not Sure**
science overall.	1	2	3	4	5	6
the physical sciences.	1	2	3	4	5	6
earth/space science.	1	2	3	4	5	6
the life sciences.	1	2	3	4	5	6
topics related to engineering.	1	2	3	4	5	6

Please rate how familiar you are with the following:

Please rate how familiar you are with each of the following:	**Not at All Familiar**	**Slightly Familiar**	**Somewhat Familiar**	**Moderately Familiar**	**Extremely Familiar**

NGSS Science and Engineering Practice 1: Asking questions (for science) and defining problems (for engineering)	1	2	3	4	5
NGSS Science and Engineering Practice 2: Developing and using models	1	2	3	4	5
NGSS Science and Engineering Practice 3: Planning and carrying out investigations	1	2	3	4	5
NGSS Science and Engineering Practice 4: Analyzing and interpreting data	1	2	3	4	5
NGSS Science and Engineering Practice 5: Using mathematics and computational thinking	1	2	3	4	5
NGSS Science and Engineering Practice 6: Constructing explanations (for science) and designing solutions (for engineering)	1	2	3	4	5
NGSS Science and Engineering Practice 7: Engaging in argument from evidence	1	2	3	4	5
NGSS Science and Engineering Practice 8: Obtaining, evaluating, and communicating information	1	2	3	4	5

Modeling
Please provide your own definition of scientific modeling:

The following section asks about your instructional practices. The first table includes what your **students** engage in while the second table includes what **you** engage in in your classroom. How often **do your students do** each of the following in your science classes?[4]

[4] From Hayes, K. N., Lee, C.S., DiStefano, R., O'Connor, D., & Seitz, J.C. (2016). Measuring science instructional practice: A survey tool for the age of NGSS. *The Journal of Science Teacher Education, 27* (2), 137-164.

	Never	Rarely (A few times a year)	Sometimes (once or twice a month)	Often (once or twice a week)	Daily or almost daily
Generate questions or predictions to explore	1	2	3	4	5
Identify questions from observations of phenomena	1	2	3	4	5
Choose variables to investigate (such as in a lab setting)	1	2	3	4	5
Design or implement their OWN investigations	1	2	3	4	5
Make and record observations	1	2	3	4	5
Gather quantitative or qualitative data	1	2	3	4	5
Organize data into charts or graphs	1	2	3	4	5
Analyze data using basic calculations	1	2	3	4	5
Write about what was observed and why it happened	1	2	3	4	5
Present procedures, data and conclusions to the class (either informally or in formal presentations)	1	2	3	4	5
Read from a science textbook or other hand-outs in class	1	2	3	4	5
Critically synthesize information from different sources (i.e. text or media)	1	2	3	4	5
Create a physical model of a scientific phenomenon (like creating a representation of the solar system)	1	2	3	4	5
Develop a conceptual model based on data or observations (model is not provided by textbook or teacher)	1	2	3	4	5
Use models to predict outcomes	1	2	3	4	5
Explain the reasoning behind an idea	1	2	3	4	5
Respectfully critique each others' reasoning	1	2	3	4	5
Supply evidence to support a claim or explanation	1	2	3	4	5

Consider alternative explanations	1	2	3	4	5
Make an argument that supports or refutes a claim	1	2	3	4	5

How often **do you do** each of the following in your science classes?[5]

	Never	**Rarely (A few times a year)**	**Sometimes (once or twice a month)**	**Often (once or twice a week)**	**Daily or almost daily**
Provide direct instruction to explain science concepts	1	2	3	4	5
Demonstrate an experiment and have students watch	1	2	3	4	5
Use activity sheets to reinforce skills or content	1	2	3	4	5
Go over science vocabulary	1	2	3	4	5
Apply science concepts to explain natural events or real-world situations	1	2	3	4	5
Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)	1	2	3	4	5
Discuss students' prior knowledge or experience related to the science topic or concept	1	2	3	4	5
Use open-ended questions to stimulate whole class discussion (most students participate)	1	2	3	4	5
Have students work with each other in small groups	1	2	3	4	5
Encourage students to explain concepts to one another	1	2	3	4	5

[5] From Hayes, K. N., Lee, C.S., DiStefano, R., O'Connor, D., & Seitz, J.C. (2016). Measuring science instructional practice: A survey tool for the age of NGSS. *The Journal of Science Teacher Education, 27* (2), 137-164.

Posttest Survey

You are being asked to complete this survey because you are a teacher in an elementary (kindergarten through sixth grade) classroom and you are currently or have participated in the Engaging Young Minds professional development. This survey investigates elementary teachers and their experiences with teaching science. Specifically, the survey will be used to investigate teachers' feelings of preparedness to teach science content (both generally and regarding grade level specific topics) as well as teachers' confidence around teaching science in their classrooms. You do not have to answer any question you do not feel comfortable answering and have the right to end the survey at any time.

Your answers will be kept confidential and will be used to inform my dissertation study. Please contact me, Nancy Hankel, with any questions or concerns via email (nhankel01@ucla.edu) or by telephone (520-440-9624).

Please rate the degree to which you disagree or agree with each of the following statements.

I feel that Engaging Young Minds has helped to further prepare me to teach…	**Strongly Disagree**	**Disagree**	**Neither Disagree nor Agree**	**Agree**	**Strongly Agree**	**Not Sure**
science overall.	1	2	3	4	5	6
the physical sciences.	1	2	3	4	5	6
earth/space science.	1	2	3	4	5	6
the life sciences.	1	2	3	4	5	6
topics related to engineering.	1	2	3	4	5	6

Please rate how familiar you are with the following:

Please rate how familiar you are with each of the following:	**Not at All Familiar**	**Slightly Familiar**	**Somewhat Familiar**	**Moderately Familiar**	**Extremely Familiar**
NGSS Science and Engineering Practice 1: Asking questions (for science) and defining problems (for engineering)	1	2	3	4	5
NGSS Science and Engineering Practice 2: Developing and using models	1	2	3	4	5
NGSS Science and Engineering Practice 3: Planning and carrying out investigations	1	2	3	4	5
NGSS Science and Engineering Practice 4:	1	2	3	4	5

Analyzing and interpreting data					
NGSS Science and Engineering Practice 5: Using mathematics and computational thinking	1	2	3	4	5
NGSS Science and Engineering Practice 6: Constructing explanations (for science) and designing solutions (for engineering)	1	2	3	4	5
NGSS Science and Engineering Practice 7: Engaging in argument from evidence	1	2	3	4	5
NGSS Science and Engineering Practice 8: Obtaining, evaluating, and communicating information	1	2	3	4	5

Modeling
Please provide your own definition of scientific modeling:

The following section asks about your instructional practices. The first table includes what your **students** engage in while the second table includes what **you** engage in in your classroom.

How often **do you think your students will do** each of the following in your science classes?[6]

	Never	**Rarely (A few times a year)**	**Sometimes (once or twice a month)**	**Often (once or twice a week)**	**Daily or almost daily**
Generate questions or predictions to explore	1	2	3	4	5
Identify questions from observations of phenomena	1	2	3	4	5
Choose variables to investigate (such as in a lab setting)	1	2	3	4	5
Design or implement their OWN investigations	1	2	3	4	5
Make and record observations	1	2	3	4	5

[6] From Hayes, K. N., Lee, C.S., DiStefano, R., O'Connor, D., & Seitz, J.C. (2016). Measuring science instructional practice: A survey tool for the age of NGSS. *The Journal of Science Teacher Education, 27* (2), 137-164.

Gather quantitative or qualitative data	1	2	3	4	5
Organize data into charts or graphs	1	2	3	4	5
Analyze data using basic calculations	1	2	3	4	5
Write about what was observed and why it happened	1	2	3	4	5
Present procedures, data and conclusions to the class (either informally or in formal presentations)	1	2	3	4	5
Read from a science textbook or other hand-outs in class	1	2	3	4	5
Critically synthesize information from different sources (i.e. text or media)	1	2	3	4	5
Create a physical model of a scientific phenomenon (like creating a representation of the solar system)	1	2	3	4	5
Develop a conceptual model based on data or observations (model is not provided by textbook or teacher)	1	2	3	4	5
Use models to predict outcomes	1	2	3	4	5
Explain the reasoning behind an idea	1	2	3	4	5
Respectfully critique each others' reasoning	1	2	3	4	5
Supply evidence to support a claim or explanation	1	2	3	4	5
Consider alternative explanations	1	2	3	4	5
Make an argument that supports or refutes a claim	1	2	3	4	5

How often **do you think you will do** each of the following in your science classes?[7]

	Never	**Rarely (A few times a year)**	**Sometimes (once or twice a month)**	**Often (once or twice a week)**	**Daily or almost daily**

[7] From Hayes, K. N., Lee, C.S., DiStefano, R., O'Connor, D., & Seitz, J.C. (2016). Measuring science instructional practice: A survey tool for the age of NGSS. *The Journal of Science Teacher Education, 27* (2), 137-164.

Provide direct instruction to explain science concepts	1	2	3	4	5
Demonstrate an experiment and have students watch	1	2	3	4	5
Use activity sheets to reinforce skills or content	1	2	3	4	5
Go over science vocabulary	1	2	3	4	5
Apply science concepts to explain natural events or real-world situations	1	2	3	4	5
Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)	1	2	3	4	5
Discuss students' prior knowledge or experience related to the science topic or concept	1	2	3	4	5
Use open-ended questions to stimulate whole class discussion (most students participate)	1	2	3	4	5
Have students work with each other in small groups	1	2	3	4	5
Encourage students to explain concepts to one another	1	2	3	4	5

Confidence (from the Science Teaching Efficacy Belief Instrument[8])

	Strongly Disagree	**Disagree**	**Neither Disagree nor Agree**	**Agree**	**Strongly Agree**	**Not Sure**
1. Even when I try very hard, I don't teach science as well as I do most subjects.						
2. I know the steps necessary to teach science concepts effectively.						
3. I understand science concepts well enough to be						

[8] In Riggs, I., & Enochs, L. (1990). Towards the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education, 74*, 625-637.

effective in teaching elementary science.						
4. Students' achievement in science is directly related to their teacher's effectiveness in science teaching.						
5. I find it difficult to explain to students why science experiments work.						
6. I am typically able to answer students' science questions.						
7. I wonder if I have the necessary skills to teach science.						
8. When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.						

How likely are you to incorporate the superhydrophobic kit into your curriculum?
Not likely Somewhat likely (50/50) Very likely Unsure

Please indicate if you are interested in any of the following (check all that apply):
□ Engaging Young Minds Follow-Up session (in partnership with local museums).
□ Share the great work you are doing, as a result of EYM by participating in an interview.
□ Share the great work your students are doing by submitting samples of student work (we are particularly interested in student models of the Superhydrophobic Lab.

Single-Administration Survey

You are being asked to complete a survey related to your experiences at EYM and teaching science. Specifically, this survey will be used to investigate teachers' feelings of preparedness to teach science content (both generally and regarding grade-level specific topics) as well as teachers' confidence around teaching science in their classrooms.

Your answers will be kept confidential and will be used to inform my dissertation study. Please contact me, Nancy (Hankel) Anguka with any questions or concerns via email (nhankel01@ucla.edu) or by telephone (520-440-9624).

Please read the informed consent below and contact me with any questions prior to completing it. If you do not have questions, please check the box indicating you Agree which will confirm you have had all your questions answered, you understand the purpose of this survey, and you are completing it voluntarily.

(Informed Consent will be inserted here)

Please select if you Agree or Do Not Agree to participate in this study.

☐ Yes, I agree

☐ No, I Do NOT Agree (if checked, will direct to a page where they may choose to go to an external website and enter their email address to be entered in the raffle)

Please provide the following:

1. Grade level you are teaching during the 2016-17 school year:
2. Number of years full-time teaching (at any grade level; **excluding** student teaching):
3. Number of years full-time teaching at the K-6 level:
4. Please indicate the year(s) you participated in EYM (select all that apply):
   2012 2013 2014 2015

5. Please select which statement most closely applies to you:
   a. I tried to register for the 2016 EYM session but could not because it was full.
   b. I considered or tried to register for the 2016 session but could not participate for another reason.
   c. I did not try to register for the 2016 session.

Please rate the degree to which you disagree or agree with each of the following statements.

I feel that my education and teacher preparation program prepared me well to teach…	Strongly Disagree	Disagree	Neither Disagree	Agree	Strongly Agree	Not Sure

			nor Agree			
science overall.	1	2	3	4	5	6
the physical sciences.	1	2	3	4	5	6
earth/space science.	1	2	3	4	5	6
the life sciences.	1	2	3	4	5	6
topics related to engineering.	1	2	3	4	5	6

I feel that Engaging Young Minds prepared me well to teach…	**Strongly Disagree**	**Disagree**	**Neither Disagree nor Agree**	**Agree**	**Strongly Agree**	**Not Sure**
science overall.	1	2	3	4	5	6
the physical sciences.	1	2	3	4	5	6
earth/space science.	1	2	3	4	5	6
the life sciences.	1	2	3	4	5	6
topics related to engineering.	1	2	3	4	5	6

Please rate how familiar you are with the following:

Please rate how familiar you are with each of the following:	**Not at All Familiar**	**Slightly Familiar**	**Somewhat Familiar**	**Moderately Familiar**	**Extremely Familiar**
NGSS Science and Engineering Practice 1: Asking questions (for science) and defining problems (for engineering)	1	2	3	4	5
NGSS Science and Engineering Practice 2: Developing and using models	1	2	3	4	5
NGSS Science and Engineering Practice 3: Planning and carrying out investigations	1	2	3	4	5
NGSS Science and Engineering Practice 4: Analyzing and interpreting data	1	2	3	4	5
NGSS Science and Engineering Practice 5: Using mathematics and computational thinking	1	2	3	4	5
NGSS Science and Engineering Practice 6: Constructing explanations	1	2	3	4	5

(for science) and designing solutions (for engineering)					
NGSS Science and Engineering Practice 7: Engaging in argument from evidence	1	2	3	4	5
NGSS Science and Engineering Practice 8: Obtaining, evaluating, and communicating information	1	2	3	4	5

Modeling
Please provide your own definition of scientific modeling:

The following section asks about your instructional practices. The first table includes what your **students** engage in while the second table includes what **you** engage in in your classroom.
How often **do your students do** each of the following in your science classes?[9]

	Never	**Rarely (A few times a year)**	**Sometimes (once or twice a month)**	**Often (once or twice a week)**	**Daily or almost daily**
Generate questions or predictions to explore	1	2	3	4	5
Identify questions from observations of phenomena	1	2	3	4	5
Choose variables to investigate (such as in a lab setting)	1	2	3	4	5
Design or implement their OWN investigations	1	2	3	4	5
Make and record observations	1	2	3	4	5
Gather quantitative or qualitative data	1	2	3	4	5
Organize data into charts or graphs	1	2	3	4	5
Analyze data using basic calculations	1	2	3	4	5
Write about what was observed and why it happened	1	2	3	4	5

[9] From Hayes, K. N., Lee, C.S., DiStefano, R., O'Connor, D., & Seitz, J.C. (2016). Measuring science instructional practice: A survey tool for the age of NGSS. *The Journal of Science Teacher Education, 27* (2), 137-164.

Present procedures, data and conclusions to the class (either informally or in formal presentations)	1	2	3	4	5
Read from a science textbook or other hand-outs in class	1	2	3	4	5
Critically synthesize information from different sources (i.e. text or media)	1	2	3	4	5
Create a physical model of a scientific phenomenon (like creating a representation of the solar system)	1	2	3	4	5
Develop a conceptual model based on data or observations (model is not provided by textbook or teacher)	1	2	3	4	5
Use models to predict outcomes	1	2	3	4	5
Explain the reasoning behind an idea	1	2	3	4	5
Respectfully critique each others' reasoning	1	2	3	4	5
Supply evidence to support a claim or explanation	1	2	3	4	5
Consider alternative explanations	1	2	3	4	5
Make an argument that supports or refutes a claim	1	2	3	4	5

How often **do you do** each of the following in your science classes?[10]

	Never	**Rarely (A few times a year)**	**Sometimes (once or twice a month)**	**Often (once or twice a week)**	**Daily or almost daily**
Provide direct instruction to explain science concepts	1	2	3	4	5
Demonstrate an experiment and have students watch	1	2	3	4	5
Use activity sheets to reinforce skills or content	1	2	3	4	5
Go over science vocabulary	1	2	3	4	5
Apply science concepts to explain natural events or	1	2	3	4	5

[10] From Hayes, K. N., Lee, C.S., DiStefano, R., O'Connor, D., & Seitz, J.C. (2016). Measuring science instructional practice: A survey tool for the age of NGSS. *The Journal of Science Teacher Education, 27* (2), 137-164.

real-world situations					
Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)	1	2	3	4	5
Discuss students' prior knowledge or experience related to the science topic or concept	1	2	3	4	5
Use open-ended questions to stimulate whole class discussion (most students participate)	1	2	3	4	5
Have students work with each other in small groups	1	2	3	4	5
Encourage students to explain concepts to one another	1	2	3	4	5

Confidence (from the Science Teaching Efficacy Belief Instrument[11])

	Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree	Not Sure
1. Even when I try very hard, I don't teach science as well as I do most subjects.						
2. I know the steps necessary to teach science concepts effectively.						
3. I understand science concepts well enough to be effective in teaching elementary science.						
4. Students' achievement in science is directly related to their teacher's effectiveness in science teaching.						
5. I find it difficult to explain to students why science experiments work.						
6. I am typically able to answer students' science questions.						
7. I wonder if I have the necessary skills to teach science.						
8. When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.						

Other Comments

Please provide any other comments or thoughts you have regarding how your participation in Engaging Young Minds affected your science teaching practice:

[11] In Riggs, I., & Enochs, L. (1990). Towards the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education, 74*, 625-637.

Interview Protocol

1. What grade level did you teach this past school year?
    a. How long have you taught at that grade level?
    b. How long have you taught at the elementary level in general?
2. What is your favorite science lesson to teach?
3. How comfortable do you generally feel when you teach science?
4. How did participating in EYM impact your confidence around teaching science?
    a. To what extent do you feel your confidence around teaching science *generally* has changed after participating in EYM?
    b. I know teachers received a kit with nanoscience content/lessons at the end of EYM last summer. Were you able to implement this content in your classrooms?
        i. *IF YES:* To what extent do you feel your confidence around teaching *nanoscience content specifically* has changed after participating in EYM?
5. How have you noticed your science instruction has changed this school year following participation in EYM?
6. If you participated in EYM in years prior to 2016, to what extent do you find yourself using what you learned at EYM this summer (2016) compared to prior years?
7. What other science PDs have you participated in at your school/district so far this year?
    a. To what extent did these PDs cover scientific modeling compared to EYM?

For the following questions, when I use the phrase "scientific modeling," I am referring to the process by which a representation of a scientific phenomenon is produced and altered given the corresponding data/evidence.

8. How did your understanding of scientific modeling change after EYM?
9. How do you incorporate modeling into your science lessons?
    a. If applicable, is this different from how you have incorporated modeling previously? If so, please describe how.

10. Please describe a lesson or unit in which you were able to really implement scientific modeling.
11. Using evidence from the ways students revised their work during the lesson or unit, how did students change their thinking?
    a. *If necessary, probe for specifics in terms of ideas or concepts that students had an ah-ha moment about.*
12. To what extent did students' understanding of the content in the model lesson differ from previous years' student understanding of the same content (e.g., if the lesson is about the water cycle, did students demonstrate quicker understanding or more confusion around the content compared to previous years?)

13. What parts of EYM did you find most helpful or most affected your science teaching?
14. What parts of EYM did you find least helpful or least affected your science teaching?

Appendix C

This Appendix contains the informed consent documents.

Informed Consent for Single-Administration Survey

University of California, Los Angeles

CONSENT TO PARTICIPATE IN RESEARCH

Evaluating a Science Professional Development for Elementary Teachers: Effects on Self-Efficacy and Perceptions of Classroom Practice

Nancy (Hankel) Anguka, Ed.D. candidate, Principal Investigator (with the support of faculty sponsor Christina Christie, Ph.D.), from the Education Department at the University of California, Los Angeles (UCLA) are conducting a research study.

You were selected as a possible participant in this study because you previously participated in the science professional development program Engaging Young Minds and are still currently an elementary school teacher in the Los Angeles Unified School District. Your participation in this research study is voluntary.

Why is this study being done?

This study investigates elementary teachers and their experiences teaching science. Specifically, this survey will be used to investigate teachers' feelings of preparedness to teach science content (both generally and regarding grade-level specific topics) as well as teachers' confidence around teaching science in their classrooms.

What will happen if I take part in this research study?

If you volunteer to participate in this study, the researcher will ask you to do the following:

- Complete an online survey

How long will I be in the research study?

Participation will take a total of about fifteen to twenty minutes.

Are there any potential risks or discomforts that I can expect from this study?

- There are no anticipated risks you can expect from the study
- If you do not feel comfortable answering any questions, you may skip the question and you have the right to end the survey at any time

Are there any potential benefits if I participate?

You will not directly benefit from participating in the study.

The results of the research may be used to help to determine how participating in EYM affects teacher science content knowledge, confidence around teaching science, which parts of EYM are most effective and which may not contribute to effective implementation to help improve EYM in the future.

Will I be paid for participating?

- You may choose to be entered in a raffle to win one of two $50 Amazon gift card as a thank you for completing the survey. Two winners will be chosen at random once all surveys have been received. Participation in the study is not required in order to participate in the raffle.

Will information about me and my participation be kept confidential?

Any information that is obtained in connection with this study and that can identify you will remain confidential. It will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of not requiring you to submit your name or the name of the school at which you currently teach or schools where you have taught previously. If you choose to enter the raffle for the Amazon gift card, you will be directed to a separate site from the survey site where you will be asked to enter your email address. This email address will only be used to contact you if you are selected as a gift card winner and will not be shared with anyone else for any reason. Your email address will not be able to be connected or linked with your survey response.

What are my rights if I take part in this study?

- You can choose whether or not you want to be in this study, and you may withdraw your consent and discontinue participation at any time.
- Whatever decision you make, there will be no penalty to you, and no loss of benefits to which you were otherwise entitled.
- You may refuse to answer any questions that you do not want to answer and still remain in the study.

Who can I contact if I have questions about this study?

- **The research team:**
  If you have any questions, comments or concerns about the research, you can talk to the researcher or their faculty sponsor. Please contact:

  Researcher: Nancy (Hankel) Anguka
  Email: nhankel01@ucla.edu
  Telephone: 520-440-9624

  Faculty sponsor: Christina Christie, Ph.D.
  Email: tina.christie@ucla.edu
  Telephone: 310-825-0432

- **UCLA Office of the Human Research Protection Program (OHRPP):**
  If you have questions about your rights while taking part in this study, or you have concerns or suggestions and you want to talk to someone other than the researchers about the study, please call the OHRPP at (310) 825-7122 or write to:

  UCLA Office of the Human Research Protection Program
  10889 Wilshire Boulevard, Suite 830,
  Los Angeles, CA 90095-1406

You will be given a copy of this information to keep for your records.

Informed Consent for Interview Participants

University of California, Los Angeles

CONSENT TO PARTICIPATE IN RESEARCH

Evaluating a Science Professional Development for Elementary Teachers: Effects on Self-Efficacy and Perceptions of Classroom Practice

Nancy (Hankel) Anguka, Ed.D. candidate, Principal Investigator (with the support of faculty sponsor Christina Christie, Ph.D. and research assistant Julie Stefan Lindsay), from the Education Department at the University of California, Los Angeles (UCLA) are conducting a research study.

You were selected as a possible participant in this study because you participated in the 2016 session of the science professional development program Engaging Young Minds, you are currently an elementary school teacher in the Los Angeles Unified School District, and you indicated your willingness to participate in an interview. Your participation in this research study is voluntary.

Why is this study being done?

This study investigates elementary teachers and their experiences teaching science. Specifically, this study will be used to investigate teachers' feelings of preparedness to teach science content (both generally and regarding grade-level specific topics) as well as teachers' confidence around teaching science in their classrooms and teachers' ability to integrate scientific modeling into their science lessons.

This interview specifically will ask you about your science teaching practice, your comfort level teaching science, how you feel participating in Engaging Young Minds affected your science teaching this year, your experience using scientific modeling this year, and your students' science models as well as your thoughts about Engaging Young Minds in general.

You will either be interviewed by myself or my research assistant, Julie Stefan Lindsay. I will ask to audio record this interview in order to ensure that I have accurate record of your thoughts and feelings. This audio recording will never be shared with anyone else. If Julie is the person who conducts your interview, she will be the only other person who has access to the audio file but if she does not conduct your interview, she will not have access to the audio file. You have the right to refuse to be audio-recorded or to review the recording after the interview takes place.

What will happen if I take part in this research study?

If you volunteer to participate in this study, the researcher will ask you to do the following:

- Possibly provide examples of student science models
- Complete an interview

How long will I be in the research study?

Participation will take a total of 60 to 90 minutes.

Are there any potential risks or discomforts that I can expect from this study?

- There are no anticipated risks you can expect from the study
- If you do not feel comfortable answering any questions, you may skip the question and you have the right to end participation at any time

Are there any potential benefits if I participate?

You may benefit from participating in the study by reflecting upon your teaching practice and the work you do with students in the classroom.

The results of the research may be used to help to determine how participating in EYM affects teacher science content knowledge, confidence around teaching science, which parts of EYM are most effective and which may not contribute to effective implementation to help improve EYM in the future.

Will I be paid for participating?

- You may choose to be entered in a raffle to win one of two $50 Amazon gift card as a thank you for completing the survey. Participation in the study is not required in order to participate in the raffle. Two winners will be chosen at random once all interviews have been conducted.

Will information about me and my participation be kept confidential?

Any information that is obtained in connection with this study and that can identify you will remain confidential. It will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of not saving any interview audio files with your name or school name attached (a code number will be used instead), not sharing identifiable information with anyone aside from myself, and not requiring you to provide personal information (e.g., school name) if you do not want to share it.

What are my rights if I take part in this study?

- You can choose whether or not you want to be in this study, and you may withdraw your consent and discontinue participation at any time.
- Whatever decision you make, there will be no penalty to you, and no loss of benefits to which you were otherwise entitled.
- You may refuse to answer any questions that you do not want to answer and still remain in the study.

Who can I contact if I have questions about this study?

- **The research team:**
  If you have any questions, comments or concerns about the research, you can talk to the researcher or their faculty sponsor. Please contact:

  Researcher: Nancy (Hankel) Anguka
  Email: nhankel01@ucla.edu
  Telephone: 520-440-9624

  Faculty sponsor: Christina Christie, Ph.D.
  Email: tina.christie@ucla.edu
  Telephone: 310-825-0432

- **UCLA Office of the Human Research Protection Program (OHRPP):**
  If you have questions about your rights while taking part in this study, or you have concerns or suggestions and you want to talk to someone other than the researchers about the study, please call the OHRPP at (310) 825-7122 or write to:

  UCLA Office of the Human Research Protection Program
  10889 Wilshire Boulevard, Suite 830,
  Los Angeles, CA 90095-1406

You will be given a copy of this information to keep for your records.

SIGNATURE OF STUDY PARTICIPANT

____
Name of Participant

__________________________________ ____________________
Signature of Participant Date

SIGNATURE OF PERSON OBTAINING CONSENT

Name of Person Obtaining Consent	Contact Number

Appendix D

This appendix contains the full results of the analyses of the survey topics related to student activities and/or practices in the classroom.

	Pretest mean	Posttest mean	*t*-test (df)	p-value
Generate questions or predictions to explore	3.28	4.16	9.6 (79)	<.001
Identify questions from observations of phenomena	2.91	3.92	8.51 (77)	<.001
Choose variables to investigate (such as in a lab setting)	2.41	3.63	10.48 (80)	<.001
Design or implement their OWN investigations	2.17	3.33	10.6 (82)	<.001
Make and record observations	3.34	4.18	7.71 (81)	<.001
Gather quantitative or qualitative data	2.99	4.01	9.46 (80)	<.001
Organize data into charts or graphs	3.00	3.93	8.68 (81)	<.001
Analyze data using basic calculations	2.63	3.86	11.1 (75)	<.001
Write about what was observed and why it happened	3.27	4.23	9.06 (82)	<.001
Present procedures, data and conclusions to the class (either informally or in formal presentations)	2.64	3.78	9.55 (80)	<.001
Read from a science textbook or other hand-outs in class	3.32	4.07	2.98 (81)	<.01
Critically synthesize information from different sources (i.e. text or media)	2.95	3.87	7.39 (82)	<.001
Create a physical model of a scientific phenomenon (like creating a representation of the solar system)	2.51	3.52	9.51 (82)	<.001
Develop a conceptual model based on data or observations (model is not provided by textbook or teacher)	3.53	2.19	11.27 (80)	<.001
Use models to predict outcomes	2.32	3.72	12.34 (81)	<.001
Explain the reasoning behind an idea	3.18	4.25	9.97 (76)	<.001
Respectfully critique each others' reasoning	2.94	4.17	12.06 (82)	<.001
Supply evidence to support a claim or explanation	3.12	4.28	11.83 (82)	<.001
Consider alternative explanations	2.93	4.08	11.49 (82)	<.001
Make an argument that supports or refutes a claim	2.83	4.10	11.24 (82)	<.001

Appendix E

This appendix contains the full results of the analyses of the survey topics related to teachers activities and/or practices in their classrooms.

	Pretest mean	Posttest mean	*t*-test (df)	p-value
Provide direct instruction to explain science concepts	3.52	3.77	2.36 (83)	0.020
Demonstrate an experiment and have students watch	2.87	3.04	1.39 (83)	0.17
Use activity sheets to reinforce skills or content	3.13	3.19	0.59 (79)	0.56
Go over science vocabulary	3.57	4.14	5.46 (82)	<.001
Apply science concepts to explain natural events or real-world situations	3.36	4.16	8.28 (80)	<.001
Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)	3.21	4.29	12.22 (83)	<.001
Discuss students' prior knowledge or experience related to the science topic or concept	3.45	4.38	10.4 (83)	<.001
Use open-ended questions to stimulate whole class discussion (most students participate)	3.59	4.45	9.4 (82)	<.001
Have students work with each other in small groups	3.81	4.60	8.75 (83)	<.001
Encourage students to explain concepts to one another	3.68	4.58	9.65 (83)	<.001

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