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The Impact of the 5E Teaching Model on Changes in Neuroscience, Drug Addiction, and Research Methods Knowledge of Science Teachers Attending California's ARISE Professional Development Workshops

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Abstract

This study examined how science teachers' knowledge of research methods, neuroscience and drug addiction changed through their participation in a 5-day summer science institute. The data for this study evolved from a four-year NIH funded science education project called Addiction Research and Investigation for Science Educators (ARISE). Findings were based on pre- and post-test evaluation data from three annual cohorts in June 2010, 2011 and 2012. Researchers found significant improvement in teacher knowledge overall and on all subscales. Teachers with lower pre-test scores showed the greatest gain in post-test scores. What made this in-service unique was that the 5E pedagogical model was used to teach the teachers and demonstrate 5E instruction in the science classroom. Through the use of the 5E teaching method, we found that teachers in our cohorts with the least skill had higher rates of gain. A strategy that has been used extensively to teach science to children, this model moves away from didactic methods of in-service pedagogy. These findings suggest that the 5E model could be an effective way to teach teachers as well as students, particularly new and or less skilled teachers, who often tend to have high numbers of English Learner (EL) students in their classes.

Keywords: 5E Model, teaching English language learners, science teacher in-service

1. Introduction

Science education research since the 1980s has focused on strategies to improve science education and develop effective school-based science education programs. Despite these efforts, there has been a decline in science education performance, especially in low-income school districts with high numbers of English Learner (EL) and minority students. In the mid-1990s, the *National Science Education Standards* (National Research council [NRC], 1996) shifted science education to more science inquiry-based approaches. More recently, the implementation of the New Generation Science Standards (NGSS) presents unique challenges for science teachers as they are charged with fostering an inquiry-based instruction through the integration of the dimensions outlined in the Framework for K-12 Science Education [Framework] (NRC, 2012). The three dimensions include: 1) science engineering practices; 2) crosscutting concepts; and 3) core ideas in each of the science disciplines. The science and engineering practices redefine the *inquiry-based science* concept as these are aligned with scientific inquiry (research methodology), and in turn help students learn, understand, and do science (Lee, Quinn, & Valdes, 2013). The science and engineering practices require students to be active participants in science inquiry by engaging in discourse about the scientific model or a science concept. In light of the NGSS and the Framework, Weinburgh, Silva, Horak Smith, Groulx, and Nettles (2014) indicate that teacher preparation programs must equip science teachers with the skills and knowledge to integrate language and science learning. The integration of language and science learning presents a more pressing challenge for science teachers of ELs.

Data indicates that more than 21% of all U.S. children in grades K-12 speak a language other than English at home (National Center for Education Statistics, 2010). In the state of California, 84.59% of the EL population speaks Spanish as their primary language. The other 15.41% is made up predominately of students who speak Asian or Southeast Asian languages, with over 60 languages spoken throughout the state (California Department of

Education, 2012). As the U.S. population is becoming more ethnically and linguistically diverse, it is crucial that science teacher preparation and professional development programs help teachers develop a science pedagogical knowledge base and pedagogical strategies that includes skills and activities that engage all students, especially EL populations, in learning science.

Given the high numbers of ELs in the U.S. classrooms, science teachers are pressed to serve as language teachers. Although there is some debate on whether language development can occur in the science classroom, Simich-Dudgeon and Egbert (2000) indicate that English speakers and EL students can jointly learn science through collaborative discourses about the science activities. The debate on science and language integration stems from the misunderstanding that scientific terminology presents a barrier to learning for ELs (Crowther, Tibbs, Wallstrum, Storke, & Leonis, 2011). Dong (2013) recommends that rather than focusing on word recognition, teachers can integrate students' previous knowledge and language in the science concept learning process. For the example, through the use of the 5E model (Bybee, 1993) can aid language acquisition by fostering a classroom environment where students are able to use their own examples and explanations.

As the U.S. population is becoming more ethnically and linguistically diverse, it is crucial that science teacher professional development programs help teachers develop a science pedagogical knowledge base and pedagogical strategies that includes skills and activities that engage all students, especially EL populations, in learning science.

1.1 Teacher Preparation

Traditionally, state policies associated with school funding, resource allocations, and tracking leave high poverty school districts with fewer and lower-quality books, curriculum materials, laboratories, and less qualified and experienced teachers. The fact that the least-qualified teachers typically end up teaching the least-advantaged students is particularly problematic in low-income school districts (Gagnon & Mattingly, 2012).

Studies have found that the difference in teacher quality may represent the single most important school resource differential of academic success between minority and white children (Ferguson & Brown, 2000; Darling-Hammond & Post, 2000). The literature on science teacher quality indicates that many teachers are not prepared to teach science content and integrate inquiry-based science instruction into their education of EL students (Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). These findings support the need to provide in-service education that is targeted to improve the science knowledge of less prepared teachers to bring them on par with their counterparts.

Other scholars have indicated that science teachers may also lack adequate preparation to address the needs of linguistically diverse students in the science classroom (Bryan & Atwater, 2002; Janzen, 2008; Lee, Hart, Cuevas, & Enders, 2004). Moreover, teacher quality is more problematic in racially diverse school districts with high levels of poverty. Gagnon and Mattingly (2012) found that schools with a high percentage of minority students are more likely to have beginning teachers. The staffing of beginning teachers in schools with high levels of poverty creates even greater academic risks for minority students, as these schools do not have the resources to support the pedagogical development of new teachers. Moreover, Miller (2011) found that teachers face greater challenges in culturally and linguistically diverse schools as they have multiple work demands, coupled with the challenge of meeting the learning needs of their diverse students. In addition, Darling-Hammond and Sykes (2003) indicated that areas of high poverty tend to have higher rates of teacher turnover.

1.2 Professional Development for Science Teachers

Since the late 1980's, one program has been modeled extensively in the development of new curriculum materials and professional development experiences is the Biological Sciences Curriculum Study (BSCS) 5E Instructional Model. In spring 2006 web-based research showed that the BSCS 5E model had been used in 235,000 lesson plans, over 97,000 posted examples of universities using the 5E model in course syllabi, over 73,000 examples of curriculum materials incorporating the 5E, over 131,000 examples of teacher education programs or resources using the 5E and three states endorsing the model (Bybee et al., 2006). Numerous articles support the 5E model for student learning (Akar, 2005; Cardak, Dikmenli, & Saritas, 2008; Acisli, Yalcin, & Turgut, 2011; Cherry, 2011; Tuna & Kacar, 2013).

In their analysis of the data from the Teacher Activity Survey collected through the Eisenhower Professional Development Program, Garet et al. (2001) found that effective teaching practices can be fostered through professional development. Previous research has indicated that professional development interventions that target science teachers of EL students need to be focused on a specific content and provide teachers with strategies on how to make the concepts accessible to ELs (Lee & Fradd, 1998; Lee, 2005; Penuel et al., 2007). Lee (2004) indicated that teachers may not have a clear idea of how to make science more accessible to ELs, but through professional development they can acquire the strategies and knowledge to do so.

Other studies have identified: 1) content-focused activities, 2) knowledge about best teaching practices for teaching science to the targeted student populations, and 3) learning how to engage students in the learning process as some of the key characteristics of effective professional development interventions (Dass, 2001; Garet et al., 2001; Penuel et al., 2007). More specifically, these studies indicated that high quality professional development for science teachers should be content-focused, model inquiry style pedagogies, and provide teachers with enhanced knowledge and skills to work with diverse student populations.

1.3 The Scientific and Engineering Practices and the 5E Model

The 5E model has been used for years in teaching science method courses (Goldston, Dantzler, Day, & Webb, 2012). The 5E model consists of five phases:

1) *Engagement*—creates student interest in the subject by generating curiosity, raising questions, and eliciting thought and responses that uncover previous knowledge.

2) *Exploration*—often working in groups, activities that provide students with concepts, skills to help them use prior knowledge to generate new ideas, and help them explore new possibilities and increase interest in the subject.

3) *Explanation*—allows students to explain their understanding of a concept. Teachers may introduce a concept or skill and provide deeper understanding and/or clarify misunderstandings.

4) *Elaboration*—encourages students to apply or extend their learning of a concept in new directions, provides opportunities to expand thinking and skills, and allows students to apply their understanding through additional activities.

5) *Evaluation*—allows for student self-assessment, allows teachers to observe student learning and look for evidence that students have changed their thinking or behavior and evaluate for student misunderstanding.

(Bybee et al., 2006; Bybee, 2009).

Use of the 5Es in science instruction can help teachers address science content as well as the scientific and engineering practices. For example, through engagement teachers can use students' prior knowledge to initiate the engagement of students in the science classroom. During the engagement phase, students can begin to *develop questions or engineering problems* by drawing from their previous knowledge. Furthermore, through exploration the students can also begin to *ask questions and define engineering problems*. Teachers can promote the *development and use of models* by encouraging students to *elaborate* on the different ways they can represent science concepts. Through the *elaboration and exploration phases*, students have the opportunity to *plan and carry out investigation* by examining the different ways they can answer scientific questions developed in the classroom and generate the evidence to test their theories. Students can also *explore* the different ways that they interpret and can make sense of the raw data. Additionally, through *explanation* the students are encouraged to find ways to communicate their data to different audiences. Exploration and elaboration allows students to find tools within the mathematical and computational fields and encourages them to apply the tools to solve their science questions and engineering problems using previous knowledge and skills in the reconceptualization of concepts and models. Teachers can foster *constructing explanations and designing solutions* by having students *explain* their rationale and their connections to science knowledge. The goal is for students to articulate in various forms the explanations of a phenomenon. By having students explain a phenomenon, teachers can evaluate students understanding and learning of the scientific ideas presented. Students are required to *engage in argument based from evidence* to defend their findings and rationale. In order to do so, students must elaborate on their thinking and procedures to provide the necessary evidence. Finally, the *obtaining, evaluating, and communicating information* practice evaluates the students' ability to communicate and reproduce the science and engineering concepts. This practice can be achieved through *evaluation* of students' performance throughout the other practices by gauging their levels of engagement, elaboration, exploration, and explanation. The use of the 5E model in the Science and Engineering Practices presents a unique opportunity for science teachers to integrate language development. Table 1 presents the Science and Engineering Practices and their alignment with the 5E Model.

Table 1. Science and engineering practices in the 5E model

Scientific and Engineering Practice	5E Model
1. Asking questions and defining problems	**Engagement** of students' prior knowledge to generate scientific questions or engineering problems based on the science content. **Exploration** can help students to ask questions and defining problems.
2. Developing and using models	**Elaborate** encourages students to expand their learning, and expand new concepts by discussing different representations of science concepts.
3. Planning and carrying out investigations	**Exploration** allows student to design comprehensive scientific investigations that generate data to support their hypotheses. **Elaborate:** The exploration phase in this practice allows the students to continue to expand their skills to become more systematic when conducting investigations.
4. Analyzing and interpreting data	**Explore:** Student must be able to explore the different ways to analyze raw data and interpret it. **Explanation** allows students to communicate the data analyses in different forms.
5. Using mathematics and computational skills	**Exploration** of tools and concepts to **elaborate** and build knowledge across the academic disciplines.
6. Constructing explanations and designing solutions	**Explanation** can help students provide solutions to their science and engineering questions by articulating in various forms causes of a phenomenon.
7. Engaging in argument from evidence	**Elaborate** allows students to defend their conclusions and findings based on the evidence formulated.
8. Obtaining, evaluating, and communicating information	**Evaluation** of students understanding of the concepts via their explanations, elaborations, and exploration.

This study examined how science teachers' knowledge of research methods, neuroscience and drug addiction changed through their participation in a 5-day summer science institute. We address the following research questions:

1) Was the Summer Science Institute successful in increasing teacher knowledge of Neuroscience, Drug Addition, and Research Methods?

2) Were there teacher demographic and situational variables that impacted teacher learning?

3) Were less experienced and/or qualified teachers more likely to teach in schools with high EL enrollment and did this impact their learning?

2. Methods

2.1 Population

The population for this study consisted of 91 science teachers who made up three consecutive cohorts of 30 to 35 teachers attending the 2010, 2011, 2012 ARISE Summer Institutes. The population included only teachers who attended the entire institute and completed both the pre and post tests/surveys. All teachers voluntarily signed up to participate in the ARISE project and the only requirement for participation was that they were teaching 7th through 12th grade science classes in public schools located in the California Central Valley.

The mean age for science teachers in the ARISE Summer Institute cohorts were 41.9 years, 62 (68.1%) were female and 29 (31.9%) were male. Regarding education: 42.3% of the participants completed some form of post-graduate education. The average number of years of post-graduate education was 5.7 years. Additional demographic information can be reviewed in Table 2.

Table 2. Characteristics of ARISE teachers in all cohorts

Teacher Characteristics	Mean/Percentage n=91	SD/Range
Age (mean years)	41.91	10.52
Male	29 (31.9%)	
Female	62 (68.1%)	
US Born	79%	
California Born	61%	
Years of Post-Grad education (mean years)	5.76	2.10
Currently Teaching EL's	53%	
Socio economic status (SES) as a Child (levels 1 to 5)	2.82	1.26
Socio economic status as Adult (levels 1 to 5)	3.96	.942
EL's in School District	34.57%	0-100%

2.2 The ARISE Program

The findings described in this article are based on data collected under the National Institute on Drug Abuse NIDA, and Science Education Drug Abuse Partnership Awards (SEDAPA) funded project, Addiction Research and Investigation for Science Education (ARISE). An essential feature of the ARISE project was to provide professional development to science teachers working in the Central Valley with a specific aim of improving teachers' neuroscience, drug addiction and research methods content knowledge such that they could lead neuroscience and drug addiction research projects in their classrooms. Neuroscience and drug addiction were chosen as the content areas for the Institutes because it was anticipated that teachers (and their students) would have greater interest and therefore greater gains in knowledge in these topic areas. An ambitious and broader goal of ARISE was to provide an important model to address the science education achievement gap that exists between ELs and English speaking students attending public schools in California's Central Valley by combining evidence-based instruction in science content with an effort to directly engage students in a drug addiction research project.

In order to better prepare science teachers in the Central Valley to improve their delivery of science instruction to students, the 5E instructional approach was introduced and modeled throughout the content delivery of the institute. This model is based on the constructivist approach to learning whereby learners build or construct new ideas on top of previous experiences and knowledge (Enhancing Education, 2002). Each of the 5Es described below actively engage students in a series of phases that help them build their knowledge and experiences, construct meaning, and assess their understanding of new information.

This study focused on the impact of the 5E teaching model to improve participant teachers' neuroscience, drug addiction and research methods content knowledge. In order to help engage students in science and foster student centered inquiry-based instruction a requirement of the ARISE Institute was that teachers return to their classrooms and lead their students in drug addiction and/or neuroscience research experiments. The research process allows students to be active participants in science inquiry by engaging in discourse about their experimental design, data collection, analyses and reporting. The importance of instruction in scientific methodology is evidenced by the fact that *Investigation and Experimentation* standards, focusing on the scientific process, were included in every grade level of the California State Science Standards (California Department of Education, 2013) and in the Framework for K-12 Science Education [Framework] (NRC, 2012).

The ARISE Institute consisted of a five-day (8-hours/day) intensive training: consisting of four hours/day of neuroscience content material with a focus on drug addiction research, 1 hour/daily of research methods training, and 3 hours/day of cultural nuanced learning and 5E Model pedagogy. Curriculum for the Neuroscience and Drug Addition content of the Summer Institute were derived from "The Brain: Understanding Neurobiology Through the Study of Addiction" an interactive curriculum for teachers and Students grades 9 through 12 (NIH, NIDA, March 2010). Major topics presented included: 1) Localization of brain function, 2) General functions of specific brain areas, 3) Anatomy of the neuron, 4) Neurotransmission, 5) Mechanism of drug action and neurons, 6) Environmental, behavioral and genetic influences on addiction, and 7) Addiction as a chronic disease. Delivery of neuroscience content included information about the nervous system, structure and function. Drug addiction presentations included a discussion of addiction and information on the classes/categories of drugs, the basics of drug pharmacology, and the effects of specific drugs on the body

Presenters incorporated stories or photos to engage the learner; detailed animated PowerPoint presentations were used to explain brain functions, action potentials and effects of drugs. Participants were allowed to ask questions when needed. Hands-on exploration included sheep brain, frog and cow eye dissections and group activities were used to demonstrate action potentials. Presenters were careful to relate new information to previous knowledge prior to elaborating on new content. Time was allowed for exploration and classroom clickers that recorded the number of correct responses to questions were used during the instructional sessions to check for understanding before moving on to new information.

The 5E pedagogical approach was introduced to teachers as a model for teaching 7th-12th grade science lessons during the first day of the workshop and was used and modeled by UC Davis science faculty workshop presenters throughout the institute. This approach was also used to demonstrate and model how to deliver 5E instruction to EL students in a separate training session supported by two texts: "Making Science Accessible to English Learners" (Carr, Sexton, & Lagunoff, 2007) and "Building Academic Vocabulary, Teacher's Manual" (Marzano & Pickering, 2005). Thus, teachers were able to both visualize science teaching strategies and discuss these strategies with faculty workshop presenters in order to better understand and implement these practices in their own science classroom settings.

2.3 Instrumentation

The educational effectiveness of the science component of the summer institutes were measured by way of a pre-test and post-test administered during the start and conclusion of each institute. A demographic survey was given during the start of each institute that collected relevant information about teacher gender, ethnic/race, educational, socio-economic background, and percent of EL students in schools where they taught science.

The Neuroscience, Drug Addiction, and Research Methods test consisted of an objective-referenced test of 24 multiple-choice items and 2 positively phrased true/false items. Seventeen multiple choice items had one correct answer and three distractors, 6 items included "All of the above", "None of the above", and "Answers a and c" as distractors and/or correct answers. One true/false question on drug addiction and the other on research methods started the test, followed by multiple-choice questions where 9 addressed drug addiction, 4 addressed research methods, and 11 addressed neuroscience. To ensure content validity, the test was developed by three university faculty members and was based on neuroscience, drug addiction and research methods content they presented during the ARISE Summer Institutes. The faculty included two members from the Department of Neurobiology, Physiology and Behavior and one from the Department of Animal Science. Neuroscience and drug addiction content followed guidelines provided by: *The Brain: Understanding Neurobiology Through the Study of Addiction* (January 2000). The test was field-tested by 15 science teachers not participating in the study. Distractor and item analysis measures were generated from these data and items with low discrimination values were removed. Reliability tests were conducted using Cochran's alpha estimates. Internal Consistency reliability estimates resulted in a value of Cochran alpha=0.520 for the pre-test and Cochran alpha=0.663 for the post-test. Table 3 presents additional reliability information for each of the cohorts.

Table 3. Cohort and exam section reliability

Exam Section	Cohort 2		Cohort 3		Cohort 4		All cohorts	
	Pre T	Post T	Pre T	Post T	Pre T	Post T	Pre T	Post T
Neuroscience	.491	.444	.335	.513	.529	.569	.329	.400
Drug Addiction	.413	.554	.491	.467	.500	.599	.253	.392
Research Methods	.306	.470	.469	.406	.290	.335	.298	.331
Cultural competency 77-86	.493	.555	.584	.664	.618	.468	.505	.493
Paper Sections 51-76	.623	.670	.600	.649	.691	.722	.501	.606
All Exam Sections 51-86	.669	.711	.679	.741	.705	.752	.520	.663

2.4 Data Collection and Analysis

The test and survey were coded to ensure teacher confidentiality and pre- and post-tests were matched by coded numbers. Teachers were asked to respond to the test using Scantron forms. These data were scanned and uploaded into an Excel data file for processing. The statistical package used in analyzing the data was SPSS. Counts and frequencies were tabulated for all teacher demographic variables. Only completed data from teachers taking both the pre- and post-test/surveys were used in the analyses (n=91). For the purpose of this article, data from the three cohorts were pooled into one group for analyses. Due to the ARISE Summer Institute focus on teaching EL students, teacher demographic and school EL percentages were used to determine relationships with high or low-test scores of content knowledge. Teachers were placed into different groups depending on the percentages of EL students in their classrooms. In order to determine if teachers had low or high numbers of EL students in their classrooms, a binary variable was created whereby low numbers of EL students in teachers' classes included those with 15% EL students or fewer (n=21) and high numbers of EL students equaled 16% or higher (n=54). This threshold was selected to reflect the average number of EL students in schools in high-income districts reported by the State Department of Education (California Department of Education, 2014). Changes in pre- and post-test scores were analyzed using t-test and analysis of covariance. Relationships between test scores and teacher independent and school variables were analyzed using descriptive statistics, t-test, cross tab and correlation analyses.

For purposes of analyses, the test was divided into three subscales based on content knowledge delivered and subsequently developed questions addressing neuroscience, drug addiction, and research methods knowledge.

3. Results

Paired t-test procedures were used to determine changes in teacher knowledge between the Neuroscience, Drug Addiction and Research Methods pre-test and post-test (n=91). A t-value of 10.19 (p=0.000) indicated a statistically significant increase in knowledge between pre- and post-test scores; indicating a significant increase in teacher knowledge. Paired t-test analyses were also calculated to determine changes in teacher knowledge between pre-test and post-test on the subscales of Neuroscience, Drug Addiction, and Research Methods. Statistically significant increase in teacher knowledge was observed (p=0.000) on the three subscales. The results of these analyses are presented on Table 4.

Table 4. Paired t-test Analyses of changes in knowledge on the Neuroscience, Drug Addiction, and Research Methods pre-test and post-test and subscales

All Cohort Subscales	n	Pretest Mean	SD	Posttest mean	SD	t-value	Probability
Neuroscience, Drug Addiction and Research Methods Test	91	10.47	2.76	14.39	3.38	10.19	0.000**
Neuroscience Subscale	91	.345	.149	.518	.174	9.03	0.000**
Drug Addiction Subscale	91	.412	.153	.572	.168	7.14	0.000**
Research Methods Subscale	91	.578	.217	.698	.195	4.34	0.000**

In general, the greatest changes in scores were observed in the Neuroscience subscale with an average change of 17.3%, followed by Drug Addiction (16%) and Research Methods subscale with 12% gains. Statistically significant differences in pre and post-test paired performance were observed in 6 out of 11 items at the p=0.05. Paired t-test analyses showed significant changes in knowledge of 7 out of 10 items on the drug addiction subscale. Paired t-test analyses were used to determine changes in teachers' knowledge of the research methods process, however, out of 5 items, only 1 item, a question on self-administration studies, showed a statistically significant change of knowledge (p=0.00).

Group t-tests were completed to examine if the number of EL students in a teacher's school influenced performance on both the pre- and post-tests. Teachers with high numbers of EL students in their schools (16% and higher) presented lower scores across all subscales on the pre-test, (t=2.39, p=0.0095) compared to teachers with low numbers of EL students in their schools. Both groups increased their test scores on the post-test, however, no differences between groups with low and high EL student enrollment were observed on the post-test (t=1.5, p=0.06). In addition, pre-test scores on the research methods subscale illuminated significant differences between teachers with low numbers of EL students in their schools compared with teachers with high numbers of EL students (t=2.6, p=0.005, n=91). However, post-test scores on the research methods subscale revealed no significant differences after the training (t=0.85, p=0.199). These finding suggest that content provided during the institutes helped minimize the score difference on the post-test, such that the number of EL students in teachers' classrooms did not influence their post-test scores.

Teachers born in the U.S. appeared to have an advantage on the pre-test, (M=11.50, n=79) particularly in the drug addiction and research methods subscales compared with teachers born outside of the U.S. (M=9.0, n=12), (Pre-test t=3.3, p=0.001). However, content provided during the institutes appeared to minimize the score difference on the post-test between groups such that there was no difference between teachers born in the U.S. (M=15.5, n=79) compared with teachers not born in the US (M=14.1, n=12) (Post-test t=1.45, p=0.14).

There were no differences between teachers having a science background (i.e., a B.S. degree or science major) (n=46) compared with teachers teaching science from non-science majors (n=41) on both the pre- and post-test scores (t=0.201, p=.84, n=87 and t=1.36, p=.17, n=87, respectively). Scores for both groups improved on the post-test, however there were no significant differences between groups (post-test M=14.9, n=41 and 15.8, n=46). Additional analyses with teachers' characteristics such as adult socioeconomic status, gender, age and diverse background showed no statistical differences in pre-test or post-test scores.

In order to determine if educational differences existed between teachers with high or low EL student enrollment in our study, we used descriptive and cross-tabulate analyses to compare teachers' education levels and the percent of EL students in their schools. A binary variable was created whereby low numbers of EL students equaled 15% or lower (n=21) and high numbers of EL students equaled 16% or higher (n=54). We found that teachers with low EL enrollment reported more years of post-secondary education (6.7 yrs.) compared with teachers with high EL enrollment (5.5 years) (t=2.17, p=02). These findings suggested that teachers in our study from schools with high EL enrollment had less years of post-secondary education compared with teachers with low percent of EL students in their schools.

4. Discussion

In-service professional development programs such as the ARISE Summer Institutes can be instrumental in increasing teacher preparedness for delivering science content to EL students. Formal instructional settings which incorporate hands-on modeling of an evidence-based instructional approach such as Bybee's 5E model are important because they go beyond a simple description of an effective teaching approach by incorporating tangible examples of the specific pedagogical techniques along with the science instruction. Rather than providing teachers with instruction on science content and pedagogical approaches separately, the literature suggests that the most effective way to demonstrate pedagogical techniques is to do so while delivering strong science content (e.g., Santau et al., 2014).

The ARISE Summer Institutes delivered inquiry-based science instruction to in-service teachers while modeling the 5E pedagogical approach; with direct examples that were designed to reach culturally EL populations. The literature suggests that the foundation of good science pedagogy is a deep understanding of science content (Aydin et al., 2013). This study examined how science teachers' knowledge of Neuroscience and Drug Addiction, and Research Methods changed through their participation in a 5-day ARISE Institute. In addition, demographic data collected from participants were used to determine if experience and socioeconomic factors influenced test scores. Additionally, relationships between teacher experience and school EL enrollment data were explored to see relationships with current literature. Below we outlined our conclusions based upon our results and suggest future research.

In general, teachers who received training during the ARISE Summer Institutes showed significant improvement in their knowledge of neuroscience, drug addiction, and research methods with the greatest gains of knowledge in the Neuroscience and Drug Addiction subscales. Teachers had the lowest knowledge gains in the Research Methods subscale. While neuroscience and drug addiction topic areas are not addressed in most 7^{th} through 12^{th} grade science classes, the State Science Content Standards (California Department of Education, 2013) touch on neuroscience in the physiology section of Biology/Life Sciences courses, traditionally taken by students in the 9^{th} grade and drug addiction is introduced into the health curriculum as early as the 2^{nd} grade, whereby students learn the effects of alcohol, tobacco and other drugs on the human body. These health topics are expanded in 7^{th} through 8^{th} grades and into high school curriculum where more health classes are offered. Following their participation in the Summer Institutes teachers in our study led their students in a research project during the next academic semester. Neuroscience and drug addiction were chosen as the content areas for the Institutes because it was anticipated that teachers (and their students) would have greater interest and therefore greater gains in knowledge in these topic areas. Our findings indicated significant gains in knowledge in all science content sections, highlighting the success of the instructional approached used throughout the institutes (5E pedagogical model). Faculty presenters demonstrated numerous strategies while presenting science lessons, including creative ways to interest and engage the teachers in the subject matter; allowing them to work in groups to explore new ideas and concepts; providing activities to help deepen understanding, encouraging teachers to extend their learning in new directions, checking for understanding before moving to another topic and asking questions to check for and correct misunderstandings.

Of the three science content areas, our participants showed the least knowledge improvement in the research methods subsection. This finding is interesting since a basic understanding of the scientific process is widely considered to be a crucial foundational component of science education. The import of instruction in scientific methods is evidenced by the fact that *Investigation and Experimentation* standards, focusing on the scientific process, are included in every grade level of the California State Science Standards (California Department of Education, 2013), starting in Kindergarten and in the Framework for K-12 Science Education [Framework] (NRC, 2012).

In our study, the smaller improvement in understanding of research methods by our participants may be due to the difference in the inherent interest in the subject matter itself, as neuroscience and drug addiction can be more engaging and interesting curriculum topics, such that the teachers are more interested to learn this information and integrate it into existing curriculum. The topics of neuroscience and drug addiction were used to increase student interest in learning science, while knowledge of research methods information was incorporated to help teachers actively engage their students in a drug addiction research experiments following the end of the ARISE Institute.

Overall the ARISE project sought to help teachers be more effective, by not only creating more effective learning environments for their students, but also by better preparing the teachers to help their own students conduct future research projects. The literature suggests that teachers make uneven gains in their knowledge base during training, improving in one aspect of teaching more easily than others (Henze et al., 2009; Aydin et al., 2013). The lack of teacher knowledge on how to conduct simple classroom experiments was an interesting finding in this study and is a subject that needs more exploration. Perhaps the research process is a topic that needs to be emphasized in science pre-service and in-service programs to better prepare science teachers to engage their students in classroom research activities.

Our findings support earlier research of Gagon and Mattingly (2012) that suggested that less qualified teachers end up teaching the least-advantaged students particularly in low-income school districts. We found that teachers in our cohorts who taught in schools with high numbers of EL students had fewer years of post-graduate education and were more likely to have non-science majors in college.

Teachers from schools with high percentage of EL students scored lower on the pre-test, particularly in the research methods section compared with teachers teaching in less diverse districts. In addition, teachers who were born in a country other than the United States had lower pre-test scores than those born within the U.S. However, teachers with the lowest pre-test scores showed the most knowledge gain on the post-test, suggesting that information was presented in a format and knowledge level that allowed teachers with fewer years of post-graduate work and less knowledge of the subject areas to learn difficult science content over the course of a week and catch up to their higher scoring counterparts. This finding is important because in the initial planning of the ARISE Institute, science content presenters were concerned that the content would be too difficult for teachers new to the subject areas. Further, these findings indicate that the 5E Model and cultural nuanced learning strategies integrated into teaching of science content could be successful in impacting teacher knowledge levels such that less skilled and less prepared teachers were able to catch up with their higher scoring counterparts on the post-test. This finding is consistent with the work of Wilson and Berne (1999), indicating that with adequate support, professional development interventions can be successful for teachers of various backgrounds and subject knowledge levels.

5. Conclusion

Our purpose with the ARISE project was to catalyze teacher education by providing culturally nuanced instruction of specific science content areas while modeling the inquiry-based 5E pedagogical approach. Overall, teachers who participated in the ARISE summer institutes improved in their knowledge of neuroscience, drug addiction and research methods. Again, these findings are consistent with Garet et al. (2001) who found that content-focused professional development has a positive impact on teacher learning. While our results point to the success of the 5E instruction model to enhance science teacher training and support in order to more effectively engage motivate, explore, explain, elaborate and evaluate teacher education, they also suggest areas for improvement, such as a basic understanding of how research is conducted. This is important since there is a large literature demonstrating the importance of incorporating engaging activities like basic classroom experiments into instruction as a means for our students to become competent with science content.

Our results are also consistent with the demographics suggested by other studies addressing the teacher and student populations in California (California Department of Education, 2012, 2014). Our participants were teachers from the California Central Valley, a region that has an increasing number of EL students. This situation of cultural diversity makes it all the more important to continue a dialog on efforts to achieve equitable education across K-12 classrooms (Lee & Fradd, 1998; Lee, 2005; Penuel et al., 2007). Teacher education that focuses on culturally nuanced learning will help to bring pedagogical strategies to these teachers with diverse student populations such that they can deliver science instruction in a way that is accessible to all.

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