

Preparing pre-service teachers to integrate inquiry science with language and literacy instruction for English Language Learners: An experimental study

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Introduction

This paper describes the findings of a research and development project that focused on preparing pre-service elementary school teachers to integrate the teaching of science, language and literacy to English Language Learners (ELL). It was designed to improve both science teacher preparation and science teaching for ELL. ELL are the fastest growing group of students in the USA. By 2010 it is expected that 40% of school age children will be ELL (NGA Center for Best Practices, 2000). In 2000, 68% of ELL were concentrated in six states: California, Texas, New Mexico, New York, Florida and Illinois – with the largest share being in California. However the number of ELL students is growing rapidly in other parts of the country: Nevada (+354%), Nebraska (+350%) and South Carolina, South Dakota, Georgia, Alabama, Arkansas, and Oregon (+200%). Although, the primary goal of science education reform is to improve student learning of science and make rigorous science content and high expectations accessible to all students, the achievement of ELL lags behind that of native English Speakers. This achievement gap has persisted for thirty years (Rodriguez, 2004).

Over the past decade, however, an extensive body of research has demonstrated that socio-cultural approaches to science teaching that integrate language and literacy into contextualized science inquiry instruction improves the achievement of ELL (Dalton, 1998; Lee, 2005; Lee & Luykx, 2004; Palincsar & Magnusson, 2001; Rosebery, Warren and Conant, 1992; Stoddart 1999; 2005; Stoddart, Pinal, Latzke & Canaday, 2002; Stoddart, Abrams, Canaday, & Gasper, 2000; Tharp, 1997; Tharp, Estrada, Dalton & Yamauchi, 2000). The Center for Research on Education, Diversity and Excellence (CREDE) identified five instructional practices based on this literature – the CREDE Five Standards for Effective Pedagogy (CFSEP): (1) Language & Literacy (LL): Teacher use of authentic science literacy tasks to support science learning. Teacher use of science discourse patterns and science vocabulary; (2) Collaborative Inquiry (CI): student-led participation in science activities with a shared goal resulting in a material or symbolic product used for or an outcome of scientific processes; (3) Complex Thinking (CT) teacher elicitation and modeling of complex reasoning of science concepts. (4) Contextualization (C): teacher elicitation of student expertise from home/community (culture) or local (environmental/natural surrounding) understandings of science-related phenomena in classroom science lessons; (5) Instructional Conversation (IC): teacher initiation of conversation that requires student scientific reasoning & dialogue. A series of research studies, using both qualitative and quantitative methods, have demonstrated that students in classrooms using the CFSEP approach show significant gains in science, reading and mathematics achievement and teachers use of this pedagogy has been positively linked to factors critical to student performance in school such as motivation, perceptions, attitudes and inclusion (Doherty & Pinal, 2004; Estrada & Imhoff, 2001; Hilberg, Tharp & DeGeest, 2000; Saunders & Goldenberg, 1999; Saunders, O'Brien, Lennon & McLean, 1998; Stoddart, 1999; 2005; Stoddart, Pinal, Latzke & Canaday, 2002; Stoddart, Abrams, Canaday, & Gasper, 2000).

Despite the rapid increase in the number of ELL and research that has demonstrated effective science instructional practice few teachers are prepared to teach science to ELL (Lee & Luykx, 2004; Rodriguez & Kitchen, 2005). The focus of this symposium is to describe the implementation of an elementary pre-service science teacher education program based on the CFSEP and analyze the impact on student teacher knowledge, beliefs and practice.

CFSEP Science Teacher Education Program

The CFSEP pre-service teacher education program was implemented in two one year post-baccalaureate elementary education programs at two universities in central and northern California. Both institutions prepare teachers to work in diverse urban schools with high populations of ELL. In the year prior to the implementation of the research program, project staff worked with the university science methods faculty and teacher supervisors to provide training in the CFSEP and to collaboratively develop the CFSEP science methods course and student teaching practicum.

The structure of the CFSEP pre-service teacher education program was based on four principles established by prior research on pre-service teacher preparation: (1) teachers need to learn new instructional approaches through the pedagogy they are being prepared to teach (Hewson & Hewson, 1988; Stoddart, 1993a; Stoddart, Connell, Stofflet & Peck, 1993; Stofflett & Stoddart, 1994); (2) The teaching of science content and subject matter methods should be integrated with knowledge about the language and culture of the students being served (Dalton, 1998; Fradd & Lee, 1995; Met, 1994; Rodriguez & Kitchen, 2005; Stoddart, 1993a; Zeichner, 2003); (3) Coherence needs to be established between the different components of the teacher education program – coursework, practicum and supervision (Stoddart, 1993b; Wilson, Floden & Ferrini-Mundy, 2001) and (4) Novice teachers need intensive feedback, coaching and support over an extended period of time from the pre-service teacher education into the beginning years of teaching (Joyce & Showers, 1995; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Speck & Knipe, 2001).

To implement these principles, the CFSEP were integrated into the two main components of the pre-service science teacher education program: (1) science teaching methods course; and (2) student teaching practicum with coaching and support in the CFSEP pedagogy by teacher supervisors and cooperating teachers who model the pedagogy. The novice teachers will also receive coaching and support for CFSEP pedagogy in the first two years of teaching. This symposium focuses on the first two components. Students in the CFSEP program began the program with a 15-week science methods course taught through CFSEP pedagogy. Students participated in group inquiry of scientific phenomena with a strong emphasis on discourse, instructional conversation and the contextualization with hands on activities, concrete explorations, observations, visual materials and models. The course included five phases of learning: (1) personal learning of science content through CFSEP; (2) study of research and practice of CFSEP through reading, discussion and observation of classroom videos; (3) analysis of science curriculum and development of lesson plans; (4) teaching an CFSEP lesson; (5) reflection, critique and revision. In each session of the course the five CFSEP teaching practices were used. Therefore, student teachers engaged in language and literacy activities, use contextualized exemplars, worked in collaborative groups and the science methods instructor used instructional conversation to challenge students to think in complex ways. All students completed a 12-week student teaching practicum in a K-6 classroom during which they had full responsibility for classroom teaching and taught three science lessons. They received coaching and support from the cooperating teacher in whose classroom they were placed and were supervised by a university teacher supervisor who visited them in their classrooms, observed their teaching performance, gave them feedback and provided a final evaluation. The university supervisors and cooperating teachers had been trained in CFSEP and have used the practices in their own instruction.

Study Design and Method

An experimental design was used to analyze the impact of the CFSEP program on the developing beliefs and practice of novice teachers. Researchers used a pre- and post-program science content assessment, attitude survey and classroom observations to compare the development of student teacher knowledge, beliefs and skills in a random sample of 50 pre-service teachers in the CFSEP teacher education programs with a random sample 50 pre-service teachers in a traditional program at the same institution.

Instruments and Data Collection

- **Science Content Assessment** The content assessment consisted of 20 multiple choice questions measuring pre-service teachers' familiarity with overarching California Science Content Standards for K-6 grade levels related to Earth Science (e.g. erosion), Physical Science (e.g. states of matter), and Life Science (e.g. photosynthesis). Other items focused on Health Education and Nature of Science ideas (California Department of Education, 2008). In many instances, items addressed topics from traditional science methods course classroom activities and assignments. These items were organized around five major categories (Earth Science, Physical Science, Life Science, Health, and Nature of Science) and then randomly reorganized for the administration of the assessment. All pre-service teachers participating in the three experimental and three control science methods course conditions completed the content assessment on the first day of instruction (benchmark/pre-content assessment) and on the last day of instruction (post-content assessment).
- **Student Teacher Survey:** The survey was developed to measure teacher beliefs about science teaching using CFSEP and the integration of language in science teaching in diverse classroom settings. Section I included items that could influence teacher beliefs and practices in teaching science to diverse classroom settings (e.g. language proficiency, formal science training, etc). Part II of the survey primarily measures instructional beliefs and perspectives related to teaching science using CREDE's Five Standards of Effective Pedagogy (CFSEP) including 1) Joint Productive Activity, 2) Development of Language and Literacy, 3) Contextualization, 4) Cognitive Complexity, and 5) Instructional Conversation. It includes 5 point Likert Scale and open response items. The survey also addresses two other categories including perspectives on 6) Nature of Science ideas (e.g. scientific method, theory-making) and 7) Cultural Deficit (negative notions of diversity or diverse learners). All pre-service teachers participating in the experimental and control science methods course conditions completed the student-teacher survey on the first day of instruction (benchmark/pre-content assessment) and on the last day of instruction (first post-survey) and after student teaching (second post-survey).
- **Observation Protocol:** The Dialogic Activity in Science Instruction (DAISI) is a classroom observation instrument developed to capture the range of teaching practices and behaviors in the classroom related to science teaching using CFSEP. As previously reported, DAISI draws builds from work developed by Trish Stoddart on science-language integration (Stoddart, Pinal, Latzke, & Canaday, 2002) and by Roland Tharp and his colleagues on effective Vygotskian principles for promoting dialogic pedagogy (Tharp, & Gallimore, 1988; Waxman, Tharp, & Hilberg, 2004). The DAISI rubric includes 14 sub-themes under each CFSEP including: Joint Productive Activity (1.

Collaboration, 2. Authority, and 3. Production), Language and Literacy (*4. Authentic science literacy, 5. Tool for learning, 6. Science discourse, 7. Science vocabulary, and 8 Primary Language*), Contextualization (*9. Personal-Home-Community Experiences and 10. Local Ecological Environment*), Challenging Activities (*11. Complexity of concepts, 12. Feedback & inquiry*) and Instructional Conversation (*13. Initiation & questioning and 14. Uptake & follow-up*). Inter-rater reliability on the DAISI was developed over the course of the two months preceding data collection. A cadre of five core observers met weekly to gain familiarity with new changes and gain inter-rater reliability. Two lead researchers first reached agreement (90%) on five different science lessons across the 14 sub-themes that were then used to check for reliability with the rest of the observers. Inter-rater agreement was gained with the rest of the team (at 80% overall). Each control and experimental group student was observed teaching science three times during the course of their twelve week student teaching practicum. All observations were conducted by one of the five trained DAISI observers. Each observation was coordinated through the cooperating teacher in charge of the classroom during periods that the pre-service teacher could execute a science lesson. Observations averaged forty minutes in length. After each observation, observers submitted into the project database copies of their scoring forms and accompanying documents of the observations (e.g. lesson plans, handouts, etc.).

Findings and Analysis

Science Knowledge and Beliefs

Knowledge of science content and beliefs about teaching science are powerful influences on teachers science instruction (Hewson & Hewson, 1988; Stoddart, 1993; Stoddart, Connell, Stofflett & Peck, 1993; Stofflett & Stoddart, 1994; Veal & Makinster, 1999). A primary premise of the project was that pre-service teachers need to learn new instructional approaches through the pedagogy they are being prepared to teach. In the CFSEP science methods course the experimental group student teachers engaged in seven sessions of personal learning of science content through the CFSEP by conducting science inquiries in small collaborative inquiry (CI) groups on science topics drawn from the California Science Standards. These included two 4th grade science topic (the Water Cycle and Weather) and two 5th grade science topics (phases of the moon and seasons). These sessions were led by an Assistant Professor of Biology trained in CFSEP. He worked with each student inquiry group on the development of a science investigation (Collaborative Inquiry); promoted science discourse and language, literacy and writing activities (Language and Literacy, LL); engaged students in studying the science concepts in the local ecology (Contextualization, C); engaged students in the analysis of data and theory development (Complex Thinking, CT); and actively engaged in discussion of the science concepts and investigation with each of the small groups (Instructional Conversation, IC).

Students in the control and experimental groups completed the pre and post survey course survey which included items on their views about the nature of science and they also completed the pre and post course content assessment. The nature of science assessment included 12 questions based on recommendations for science literacy from *Science for All Americans* [Rutherford & Ahlgren, 1990]. These included questions such as *Elementary science teaching should demonstrate that the natural and physical world can be explained through scientific reasoning.*

After the intervention, the experimental group had a better understanding of the nature of science. They were better at correctly identifying a scientifically testable question ($p < 0.028$) and were more likely to agree with the statements that science instruction should: “be consistent with the way scientists do science” and “start with student-generated questions” ($p < 0.048$ and 0.082 , respectively).

Student teachers also completed pre- and post course survey items about their confidence in teaching science. At the baseline administration of the survey, the efficacy beliefs of most pre-service teachers toward teaching *earth science*, *life science* and *science methods/inquiry* were more often rated as being “unsure” or “somewhat prepared to teach”, with *physical science* being rated as the science domain they felt “not prepared” to teach. These findings were highly correlated with their science education background, the least educational background in science, the less prepared pre-service teachers felt prepared to teach science. In the post-survey there were significant differences between control and experimental groups with a significant shift towards confidence in the experimental group ($p < .05$). Experimental group students also improved in their content understandings showing better content understanding in their ability to correctly answer an earth science question regarding fossilization in sedimentary rocks ($p < 0.073$).

Student Teacher Beliefs about CFSEP

Pre-service teachers in both control and experimental conditions were administered the survey twice during Fall 2007, at the onset and end of their science methods course in the teacher education program. The survey included clustered items (on a Likert Scale) that asked for pre-service teacher opinions about science education scenarios that represented the CFSEP. Each cluster of questions had positively and negatively worded items that supported or offered counterviews to the CSFSEP. Figures 1, 2, 3 and 4 show pre- and post-test changes in control and experimental group teachers views about Joint Productive Activity, Language and Literacy, Cognitive complexity and Instructional Conversation. Several trends were noted from this data set, including:

- There was a percentage gain in numbers of positive responses (agreement with CFSEP) across all clusters.
- Across clusters, participants in the experimental condition outperformed control condition participants in gain scores from pre- to post- survey.
- Percentage of agreement with negative responses (disagreement with CFSEP) from pre- to post- test was higher for control participants than those in the experimental condition.
- Infusing science with authentic language and literacy activities as well as contextualizing science activities with student experiences were the least changed dispositions.

Beliefs about Integrating Language, Literacy and Science Education

Of particular interest are the changes in student teachers beliefs about integrating science, language and literacy activities. Instruction around language and literacy development generally works to provide students with opportunities for written or verbal language expression *and* development. Students have opportunities to interact with peers and the teacher, and the teacher

assists students' language development by questioning, listening, rephrasing, or modeling. In this project, there is a particular focus on promoting (1) authentic science literacy; (2) the inclusion of science tools for learning; (3) attention to oral science discourse; (4) science vocabulary and (5) the primary language.

Twenty-three survey items were developed to measure teacher beliefs about infusing language and literacy instruction into science. These included positively phrased items such as:

- *Teacher should try to use as many language modalities (e.g., reading, writing, listening, speaking) as possible to make science understandings accessible to English learners.*

and negatively phrased items such as:

- *“English learners need to be proficient in English language, reading and writing before they are taught science.”*

Students rated each of these items on a 5 point Likert Scale from Strongly Agree to Strongly Disagree. Reliability testing of the item on the Language and Literacy subscale (n=23) yielded strong results (Cronbach's alpha .88).

There were significant differences in the pre- and post- test comparisons of the control and CFSEP experimental groups on the Language and Literacy subscale. Before they took their science methods course the majority of the pre-service teacher candidates in both groups believed that literacy should be taught independent of science. That integrating science and literacy would be detrimental to the teaching and learning of both subjects. When asked the percent of science instruction that should be spent on reading and writing, pre-service teachers, most often noted “less than 10%”. They believed science was about doing hands on activities. In the post assessment these views had changed significantly in the experimental group with the CFSEP students now supporting the integration of science, language and literacy and stating that “30-50%” of time in science instruction should be devoted to language and literacy activities. There were no significant pre- post group differences in the control group.

Observations of Teaching Practice

Student teachers in the control and experimental groups were also observed three times teaching science during their student teaching practicum. These observations were coded using the Dialogic Activity in Science Instruction (DAISI), a classroom observation instrument developed to capture the range of pre-service teaching practices and behaviors in the classroom related to science and language/literacy integration. Several trends were noted from the pre- and post-analysis of this data set, including:

- Overall, experimental group participants outperform control group participants in using DAISI teaching practices. While, *Written Language (WL)* and *Oral Language (OL)* development in science was supported with more frequency for experimental participants than for control participants, attention to language of and for science learning was mostly not present in our observations.

- Comparing developmental points of implementation (low, medium, and high) within groups show parallel implementation of *Joint Productive Activity (JPA)* and *Instructional Conversation (IC)* and stronger differences on the emergence of *Contextualization (CX)* and *Challenging Activities (CA)*.
- Experimental group participants with low and medium levels of implementation within this group are twice as successful in engaging students in *Challenging Activities(CA)* in science than lower scoring control participants. *Contextualization (CX)* is also the standard with the greatest difference between groups and by levels implementation.

ANOVA analysis showed that differences on seven DAISI measures were statistically significant, and of these, scores were higher for the treatment group.

Two of the language and literacy sub-measures were of particular interest science discourse and primary language. The mean of *Science Discourse* was higher for the treatment compared to the control group, 1.43 and 1.069 respectively ($F_{(1,57)} = 5.87, p < .05$). This indicates that the experimental group pre-service teachers used more science discourse patterns (evidential, interpretive, evaluative, or methodological) to delivery their science lessons. Similarly, the *Primary Language* measure was higher for the treatment group (.841) than for the control group (.026), ($F_{(1,52)} = 26.80, p < .001$). This indicates that treatment pre-service teachers more often used students' primary language in at least one mode (speaking, reading, writing, listening) as a way to bridge the science academic language of the classroom.

Moreover, other significant differences related to other DAISI domains suggest a relationship to language and literacy and science integration are related in unexpected ways to contextualization, cognitive complexity, and dialogic learning. For example, pre-service teachers in the treatment group had a higher mean compared to the control group on the *Personal-Home-Community Experiences* measure, 1.00 and .619 respectively ($F_{(1,56)} = 8.61, p < .01$) and the *Local Ecological Environment* measure (1.01) compared to the control group (.66), ($F_{(1,57)} = 5.84, p < .05$). This indicates that the experimental group participants relied more on contextualizing teacher moves to connect relevant ecological and cultural experiences to science learning. Additionally, the *Complexity of Science Concepts* measure showed a higher mean for the treatment group (1.52) compared to the control group (1.02), ($F_{(1,57)} = 11.21, p < .001$). This indicates that the treatment group more frequently addressed the scientific method (hypothesis, experimentation, evidence, inquiry, analysis, multiple trials, etc.) than control group participants.

Conclusion

Elementary school teachers face a challenge with engaging an increasingly linguistically diverse population of students in learning about the full array of academic disciplines. This challenge is particularly significant in science, a discipline where few elementary teachers are well-prepared to teach. With these low levels of preparation, it is not surprising that many teachers feel inadequately prepared to teach science. This issue is compounded by the fact that teachers feel unprepared to work effectively with students from culturally and linguistically diverse backgrounds, particularly addressing the language and literacy demands and possibilities found within content areas. Little is currently known about the role that pre-service teacher preparation can play in addressing these discontinuities. The results indicate that the CFSEP pre-service

teacher education program significantly improved pre-service teachers understanding of and ability to use culturally and linguistically responsive pedagogy in science instruction.

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