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INTEGRATING SCIENCE AND LITERACY FOR YOUNG ENGLISH LEARNERS: A PILOT STUDY

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This pilot investigated the promise of positive outcomes in literacy, science, and social behavior on K–2 English learner (EL) students after two months of implementation of the Science Inquiry Centered Argumentation Model (ScICAM)—a systematic teaching approach to science learning that integrates literacy instruction and argument-based inquiry. The sample included 17 teachers and 31 EL students. Results indicated that teacher practices (proximal outcomes) aligned well with the ScICAM approach and resulted in increases in EL student learning (distal outcomes). Teacher increase in the use of inquiry and writing scaffolds and student growth in the ability to express understandings through oral and written modes also suggested that ScICAM practices are supportive of key practices identified by the Next Generation Science Standards (NGSS Lead States, 2013). These results highlight the merit of pursuing larger, long-term projects that collaborate with teachers on developing and implementing ScICAM interventions.

Keywords: English language learners, integrated science and literacy instruction, Science Inquiry Centered Argumentation Model, science writing heuristic

There is an urgent need for several reasons to investigate the effectiveness of existing instructional models that support simultaneous literacy and content development among young English learners (ELs). First, there a substantial increase in ELs in U.S. schools (Goldenberg, 2008), particularly in elementary grades. Second, research consistently documents a persistent EL gap in science and literacy (Fry, 2008; Reardon & Galindo, 2009). Third, there is a noted lack of EL preparation among content-area teachers (Lucas, Villegas, & Freedson-Gonzalez, 2008). Finally, empirical evidence suggests that integrated science and literacy professional development specifically addressing teacher skills in meeting ELs' learning and social needs improves academic outcomes (e.g., Lee, Maerten-Rivera, Penfield, LeRoy, & Secada, 2008). An additional need is to investigate the impact of instructional models on ELs' social adjustment within the discourses of the school (i.e., adaptation to school-based behaviors and language use norms; Gee, 1989; see also August & Shanahan, 2006; Zuengler & Miller, 2006), a question rarely investigated in integrated science-literacy instructional intervention studies. In this paper, we define (a) *literacy* as students' ability to use language effectively for oral communication, reading, and writing; (b) *science literacy* as students' science content knowledge, inquiry skills (the ability to design and conduct investigations), and reasoning/argumentation skills (the ability to build explanations); and (c) *social adjustment* as students' positive self-concept, self-control, effective approaches to learning, and effective interpersonal (with peers and adults) interaction skills.

The purpose of this pilot was to conduct a preliminary investigation of the promise of positive outcomes of the Science Inquiry Centered Argumentation Model (ScICAM; Norton-Meier, Hand, Hockenberry, & Wise, 2008)—a systematic approach that integrates literacy instruction in the context of active, argument-based inquiry science learning—with a small sample of elementary teachers working in schools with large EL populations. This preparatory work will establish a basis for the ScICAM approach to warrant larger scale, randomized controlled trial investigations to examine the approach's effectiveness with ELs. The following research questions guided this study:

1. What are general education and English as a second language (ESL) teachers' perceptions of the adequacy of the ScICAM approach to support EL needs?
2. To what extent do teachers implementing the approach internalize the ScICAM practices?
3. Does the approach's implementation show a promise of EL student: (a) overall positive outcomes, both academic (literacy and science) and behavioral (social adjustment)? and (b) positive outcomes in two specific domains—writing and argumentation—focal to the ScICAM approach as discussed in the theoretical framework?

Theoretical Framework

The ScICAM Approach

The ScICAM approach is a K–2 adaptation of the Science Writing Heuristic (SWH; Hand, 2008; Hand & Keys, 1999). The approach was demonstrated as successful in improving science (biology, chemistry, general science) and literacy achievement of native English-speaking students of varied ages (e.g., Akkus, Gunel, & Hand, 2007; Shelley, Gonwa-Reeves, Baenziger, Hand, & Therrien [in press]). Akkus et al., for example, found that the high level of the approach's implementation significantly reduced the gap in science between high- and low-achieving secondary (Grades 7 through 11) students. The results indicated that whereas the gap between high- and low-achieving students was 1.23 standard deviations in high-quality traditional classrooms, it was only 0.13 in high-quality SWH classrooms. Further, a recent study (Chanlen & Hand, 2011) of Grade P-8 students enrolled in rural-area public schools found that students immersed in the approach had larger gains in critical thinking across three years of program participation. The results indicated that the gains of the treatment students were two to three times larger than those in the traditional classrooms across all comparison groups, including low-SES and special-needs–status students (effect sizes range: 0.43–0.88).

The ScICAM approach builds on a rich history of research on ways to integrate literacy and science (e.g., Bereiter & Scardamalia, 1987; Keys, 1999); unlike its predecessors, however, the approach is more of an *argumentation structure* that assists students in engaging in the thinking and the language use of scientists. Specifically, the approach provides (a) students with a template to guide science activity while using language and literacy as learning tools, and (b) teachers with a template of suggested strategies to guide student learning (see Table 1; for more details, see Norton-Meier et al., 2008). These templates serve to support "a number of features of scientific work—such as the collaborative and constructive nature of science research—as students are led through a cycle of investigation, communication of initial results, revising and clarifying claims and reasoning, and refining explanations for phenomena" (Moje, 2007, p. 21).

The ScICAM Theoretical Model

In previous research investigating teachers' embedding of language practices into science inquiry, our thinking about how children learn science was framed by Halliday's (1975) learning theory. This Halliday-inspired theoretical frame incudes three learning processes centered on science inquiry: (a) *living the language of science*—building deeper conceptual understandings and communication skills from background experiences; (b) *learning through the language of science*—language use in the act of inquiry and meaning-negotiation serving as a catalyst for deepening understanding; and (c) *learning about the language of science*—explicit instruction focused on language and literacy skills allowing students to attach words to experiences and to build the knowledge of language forms for explanation and communication of science ideas.

Table 1 *The ScICAM Inquiry Templates*

Student Template	Teacher Template
Beginning ideas—What are my questions? (I wonder . . . I want to know . . . What if?)	Pre-investigation activities—Exploration of pre-instructional understandings within selected domain (e.g., through individual or group concept mapping)
Tests—What did I do? (Let's find out!)	Investigation activity—Informal writing, observations, brainstorming, negotiating questions
Observations—What did I see?	Negotiation I—Individual writing in science notebooks
Claims—What can I claim? (I think . . .) Evidence—How/Why do I know? (Because . . .)	Negotiation II—Individual writing of personal meanings in science notebooks followed by sharing/comparing results in small groups
Reading—How do my ideas compare with other ideas? (Ask the experts.)	Negotiation III—Compare science ideas with textbook and other resources ("consulting the expert")
Reflection—How have my ideas changed? (Now I know . . .)	Negotiation IV—Individual reflective writing ("text reformulation")
Public Sharing—What have I discovered? (Now I know . . .)	Post-investigation activities—Exploration of post-instructional understandings through concept mapping, discussion, and formal writing ("big ideas debates")

Note: Based on Hand and Keys (1999) and Norton-Meier et al. (2008).

These learning processes, in turn, are supported by three key classroom structures: (a) *teacher as decision maker*—instructional decisions that "capitalize on children's intellectual, linguistic and cultural knowledge to expand possibilities for learning" (Whitmore, Martens, Goodman, & Owocki, 2005, p. 319); (b) *collective zone of proximal development*—learning is perceived as the process of both personal and social negotiation of meaning (Vygotsky, 1978); and (c) *symmetric power and trust relationships*—teachers enable students to control their own learning (Moll & Whitmore, 1996). Figure 1 displays a graphic representation of the ScICAM theoretical model.

As shown in this figure, it is in the act of inquiry that the three circles of language and negotiated meaning—representing aspects of scientific argumentation and reasoning—and the three rectangles representing the supporting classroom structures come together. This conceptualization of science learning is grounded in science education literature (Jiménez-Aleixandre, Bugallo Rodríguez, & Duschl, 2000; Lemke, 1990) and current reform documents emphasizing integration of language and content learning (i.e., Common Core State Standards Initiative [CCSSI], 2010; Next Generation Science Standards [NGSS], 2013). According to Jiménez-Aleixandre et al. (2000), argumentation initiates students into the science-in-the-making process by engaging them in making "decisions about beliefs, judgments, and actions of inquiries" much in the same way as practiced by scientists (p. 758). Thus, instruction in the ScICAM approach is focused on engaging students with scientific inquiry—a condition necessary to promote argumentation—and on the development of student argumentation skills (e.g., connections between claims and conclusions, reasoning about claims), thus supporting students' *doing* and *talking science* (Lemke, 1990).

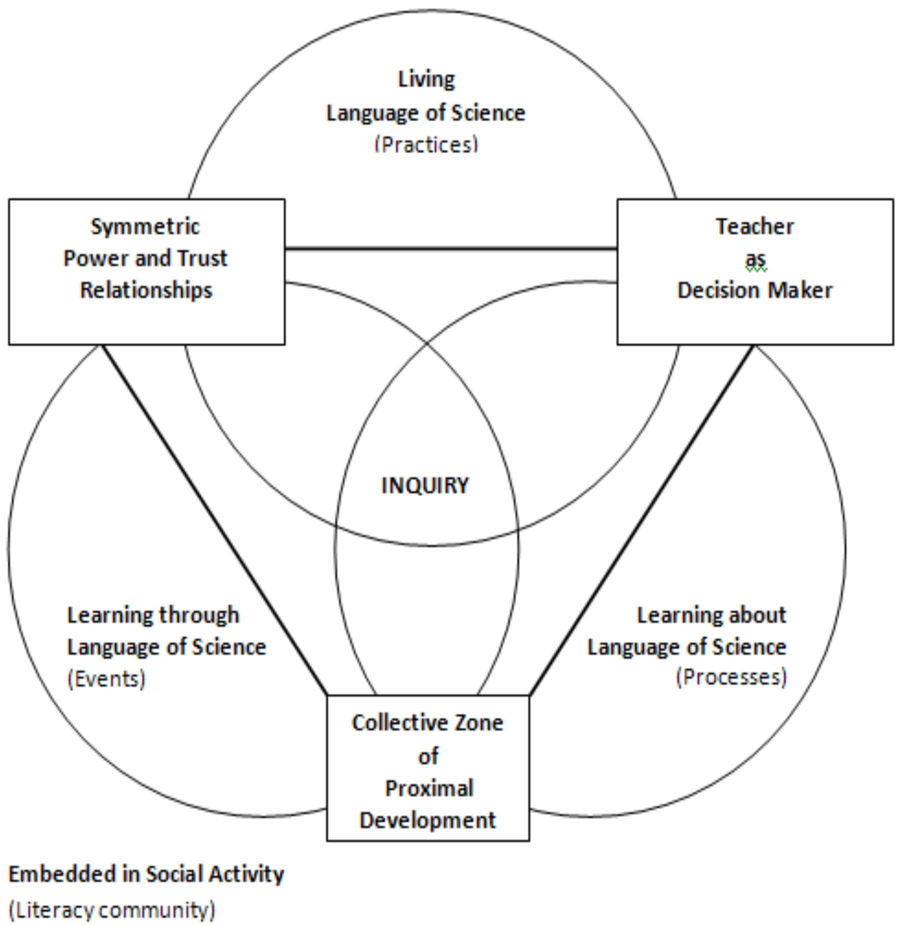

Figure 1. *ScICAM Theoretical Model (adapted from the work of Halliday, 1975).*

The Language of Science

While the ScICAM approach adopts a broad definition of science literacy (i.e., including multiple components such as critical thinking, habits of mind; Yore, Pimm, & Tuan, 2007), Schleppegrell's (2004) functional linguistics approach is a useful tool in understanding the role language plays in science. In this perspective, the language of science is perceived as "a set of [linguistic] options" available for construing the specialized knowledge of the discipline (p. 7). Among science-specific rhetorical devices, researchers have identified: *nominalization* (e.g., "evaporate" to "evaporation"), *technical vocabulary* (e.g., "mitosis"), *density* (i.e., number of content words per phrase), and *authoritativeness* (passive voice, generalized participants, hidden evaluations). While adding precision, credibility, and objectivity to the discourse, these devices may also contribute to the abstraction of scientific texts and hinder comprehension (Schleppegrell, 2004), especially for ELs. As a possible solution, researchers (e.g., Tibbs & Crowther, 2011; Zwiers, 2007) recommend pedagogical approaches that effectively balance focus on *form* (vocabulary, functions) and focus on *meaning* (context-embeddedness). Such balanced focus in science translates into providing linguistic scaffolds while engaging students in inquiry, supported by the reading of related expository and literary texts.

It is important to note that embeddedness provides opportunities for what in the ScICAM framework is termed "*just-in-time*" *teaching*, instruction focused on providing linguistic form (word-, sentence-, and discourse-level instructional scaffolds) when there is a need for students to understand and internalize some of the more technical features of language use. Examples of the ScICAM linguistic scaffolds at the word, sentence, and discourse levels include teachers' providing: (a) scientific terminology during investigations and pressure on students to use this terminology in appropriate contexts; (b) sentence starters to support students' formulating claims, questions, and justifications and "linking sentences" embedded within concept maps helping students see and express the semantic relationships among scientific phenomena; and (c) mini-lessons on cohesive devices using graphics to support paragraph organization in writing (for more examples, see Norton-Meier et al., 2008). These varied linguistic scaffolds serve to avoid a common shortfall of teaching science to ELs exclusively as isolated vocabulary, provide students with the lexico-grammatical means to express the relationships among scientific phenomena, and afford students with means to engage in "meaning-rich discursive practices in the science learning community" (Richardson Bruna, Roberta, & Perales Escudero, 2007, p. 37).

Alignment of ScICAM and New Generation Science Standards

Twenty-six states, including New York, actively participated in the development of the Next Generation Science Standards (NGSS, 2013) as Lead State Partners (see the full participating states list at http://www.nextgenscience.org/lead-state-partners). A number of these states have adopted the NGSS as their state standards in science; others are actively considering such adoption. Based on past experiences with prior national science education standard guidelines—*Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) and *National Science Education Standards* (National Research Council, 1996)—the existence of the well-developed NGSS is likely to heavily influence nearly all state science standards, even in states choosing not to adopt the NGSS directly. Thus, alignment of ScICAM with the NGSS core elements is an important aspect to consider in terms of pragmatically recommending the approach to designing and delivering Grades K–2 science instruction.

The NGSS incorporate two key emphases that are qualitatively different from those in prior national standards. The first emphasis is the critical importance of cohesiveness. As noted in the NGSS Fact Sheet (2013), "The emphasis of the NGSS is a focused and coherent progression of knowledge from grade band to grade band, allowing for a dynamic process of building knowledge throughout a student's entire K–12 scientific education" (p. 1). This intentional coherence of science concepts built into the NGSS underscores the importance for all students, including those in Grades K–2, of receiving strong science instruction. The second new NGSS emphasis is on intentionally interweaving the three dimensions of science learning: (a) *disciplinary core ideas*—science concepts and principles; (b) *cross-cutting concepts*—concepts that span all science disciplines and bind the diverse fields of science into a coherent, conceptual whole; and (c) *science and engineering practices*—the doing of science. Notably, the latter concept emphasizes a range of cognitive, social, and physical practices needed for students to engage in science inquiry and engineering design.

The ScICAM approach aligns particularly well with at least six of the eight essential science and engineering practices threaded throughout the NGSS, namely: (a) planning and carrying out investigations; (b) asking questions (for science) and defining problems (for engineering); (c) constructing explanations (for science) and designing solutions (for engineering); (d) engaging in argument from evidence; (e) obtaining, evaluating, and communicating information; and (f) analyzing and interpreting data. As is clear from a brief review of this subset of recommended science practices, students of all ages, including in Grades K–2, need to develop their abilities to both *do science* and to *communicate about science*—two essential practices of engaging with science, as defined by the NGSS. (A document aligning the ScICAM theory, EL research, ScICAM active ingredients, and the NGSS essential practices can be accessed at http://louisville.edu/education/centers/crmstd/alignment-ngss.docx)

As Bunch (2013) noted, the kinds of learning activities and outcomes encouraged by the NGSS have emphasized the centrality of language in teaching and learning science. These reciprocal connections are also highlighted in the Common Core English Language Arts (ELA) State Standards (CCSSI, 2010), emphasizing stronger literacy expectations across all subject areas, including in science. Thus, our study seeks to investigate the ScICAM model as one approach for systematically and meaningfully integrating instruction in both science and literacy, as emphasized by current standards in both disciplines.

Methods

The two-stage pilot employed a mixed-methods design. In Stage 1, 17 elementary teachers working at two schools providing English as a second language (ESL) services evaluated the adequacy of the ScICAM curricular materials (the book) for use with ELs in a survey study. In Stage 2, eight teachers (four general education, four ESL) from the larger sample, working in the same school, developed ScICAM units (one per grade level) in a professional learning community format, and with researchers' support and implemented these units in their classrooms. The impact on teacher practices was evaluated by self-report, pre-post implementation changes, and external observations by the research team. The implementation impact on ELs' learning was evaluated using a within-subjects, pre-/post-test, quasi-experimental design. In this paper, we report primarily on the quantitative findings of the two-stage pilot.

Participants and Settings

A total of 17 elementary teachers (12 general education, 1 resource, 4 ESL; 100% female) participated in this study. The participants have taught, on average, for 11 years (M = 11.5; range: 2–29) and have served, on average, over 100 EL students (M = 112; range: 12–550) during their teaching careers in U.S. schools. All ESL specialists were ESL-certified and/or endorsed (an ESL endorsement is a state-approved program of study, typically 4–5 specific courses, that can be added on to an existing teaching certificate); two general education teachers were working on completing their ESL endorsements during the study. All general education teachers had completed at least one science methods course as part of their teacher preparation programs.

A total of 31 EL students (7 kindergarten, 13 Grade 1, 11 Grade 2; 65% female; M_{age} = 6.7), attending the same school, participated in this pilot study. The students had, on average, an intermediate English proficiency (median = 3.6; actual range: 1.3–5.8; possible range: 1.0–6.0) as measured by Assessing Comprehension and Communication in English State-to-State for English Language Learners, ACCESS for ELLs® (World-Class Instructional Design and Assessment [WIDA], 2008). Most students (about 70%) spoke Spanish at home; other home languages included Mandarin, Swahili, and Karen.

Both urban schools participating in this study served K–5 students and were similar in demographics (70% to 75% minority students; 67% to 82% students on free/reduced-price lunch). Both schools provided pull-in ESL services, with general education and ESL teachers co-planning and co-teaching in integrated EL/non-EL classrooms. Science instruction in both schools used the FOSS curriculum (Lawrence Hall of

Science, 2002), with teachers following week-by-week, district-developed curriculum maps outlining three science units per grade level (each allocated about three months of instructional time). Science instruction was typically delivered in blocks of 40–50 minutes, about twice a week.

Data Sources

Book Evaluation (BE)

This survey comprised three parts. BE: Part 1 elicited teacher ratings of the appropriateness for use with ELs of individual ScICAM active ingredients (12 items; see Figure 2) and overall value (1 item) using four semantic differential scales: pointless/relevant, useless/useful, unrealistic/realistic, and boring/engaging. Semantic differential scales were assigned scores on a 5-point scale ranging from 1 (the lowest rating) to 5 (the highest rating). BE: Part 2 elicited teacher self-ratings of instructional practices in applying the 12 ScICAM active ingredients in working with ELs. Items were rated on a 4-point scale in terms of frequency of use: 0 = *never*; 1 = *occasionally*; 2 = *frequently*; 3 = *all the time*. BE: Part 3 elicited chapter-by-chapter, open-ended evaluative comments.

ScICAM Observation Protocol

The ScICAM Observation Protocol—adapted from two instruments, the Reformed Teaching Observation Protocol (a measure of science teaching practices; reliability statistics: .88–.97; Sawada et al., 2002) and Sheltered Instruction Observation Protocol (a measure of EL teaching practices; reliability statistics: .92–.99; Echevarria, Short, & Powers, 2006)—included 29 items grouped under six subscales (item range: 4–7) aligned with the ScICAM theoretical framework (Figure 1). The six subscales were: (1) *living the language of science* (e.g., "The teacher encouraged and/or took advantage of students' past learning or connections with life experiences to enhance their argumentation"); (2) *learning through the language of science* (e.g., "Students made predictions, estimations and/or hypotheses and devised means for testing them"); (3) *learning about the language of science* (e.g., "Science argumentation structures—formulating claims, questions, justifications—were emphasized: Introduced, written, repeated, highlighted, modeled, or mini-lessons provided"); (4) *teacher as decision maker* (e.g., "This lesson encouraged students to seek and value alternative modes of investigation and/or of problem solving"); (5) *collective zone of proximal development* (e.g., "There was a collaborative nature to student work"); and (6) *symmetric power and trust relationships* (e.g., "Teacher's feedback, discussions, and non-verbal actions were oriented to promote student self-confidence in providing original and/or exploratory answers"). Items were scored on a 5-point scale: 0 = *non practicing*, 1 = *beginning*, 2 = *emerging*, 3 = *understanding*, and 4 = *practicing regularly*.

Work Sampling Checklists

Work Sampling Checklists, a curriculum-embedded continuous progress performance assessment (Meisels, Liaw, Dorfman, & Nelson, 1995) served as the measure of student outcomes. The checklists included 40 items grouped in three scales: (1) *literacy* (e.g., "Student uses expanded vocabulary and language for a variety of purposes"); (2) *science* (e.g., "Student records observations with data with pictures, numbers, and/or written statements"); and (3) *social behavior* (e.g., "Student uses simple strategies to make social decisions and solve problems"; α range: .91–.95). Each scale included 3–4 subscales (α range: .60–.92). For example, the *science* scale included three subscales: *content knowledge*, *conducting investigations*, and *building explanations* (sample items for the latter subscale, as well as for *social behavior* subscales, are provided in the Data Analyses and Results section, below). Items were rated on a 3-point scale: 0 = *rarely demonstrates*, 1 = *sometimes demonstrates*, 2 = *consistently demonstrates*.

Data Analyses and Results

Research Question 1

Teacher evaluations of the ScICAM active ingredients were analyzed using descriptive statistics and graphic representation (BE: Part 1; see Figure 2) and content analysis (BE: Part 3). The results indicated that all participating teachers rated the ScICAM's active ingredients as *relevant*, *useful*, *realistic*, and *engaging* (mean ranges: 4.5–4.9, 4.3–4.9, 4.1–4.8, and 4.1–4.9, respectively). Analysis of open-ended items corroborated these results. Among 44 evaluative comments, 95% described the approach as appropriate for use with ELs. Individual comments identified both structural features (such as grouping configurations, hands-on activities) and instructional features (multiple build-in modalities to construct meanings and express learning such as graphic organizers, concept maps, speaking-reading-writing connection activities) of the ScICAM approach as supportive of ELs' needs, illustrated by the two following quotes:

> Teacher 1: I see myself allowing students more opportunity to explore content they are passionate about and permitting students to partner share or work in small groups following the guidelines listed within the book: This will help students link one idea to another and eventually progress in their scientific thinking, thus increasing the academic ability of our [ELs].

> Teacher 2: This book supports using pictures and oral language to assist [EL] students—combining the concept maps with pictures and their home language should help them acquire the knowledge in a more meaningful way.

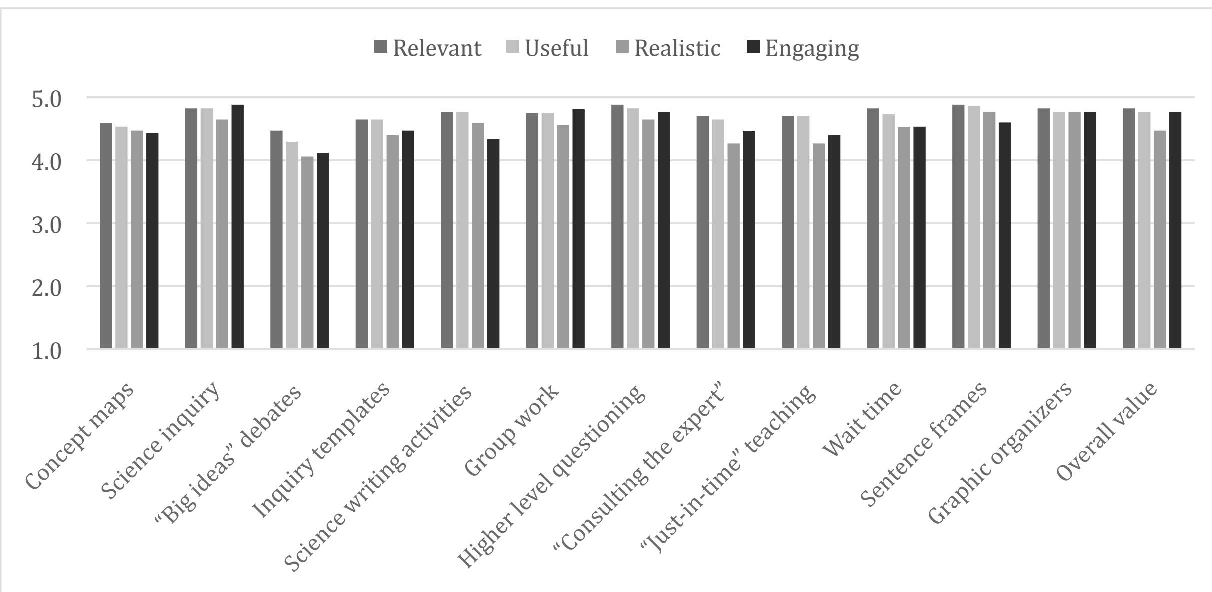

Figure 2. *Teacher ratings of the ScICAM active ingredients.* N = *17.*

Research Question 2

The ScICAM implementation level was analyzed using descriptive statistics and graphic representation (BE: Part 2; pre-post) and descriptive statistics (the ScICAM Observation Protocol). For the former, a rating of "frequently" was chosen as a meaningful cutoff for characterizing the effective ScICAM implementation level (this served as the interpretative framework for results reported in Figure 3). This decision was grounded in a philosophy that all of the ingredients would reasonably be pedagogical indicators of effective teaching and therefore used on a frequent basis. Figure 3 results demonstrate that, on average, the teachers moved from the less than "frequently" (pre) to the at least "frequently" (post) category for the use of four key ScICAM ingredients: concept maps, inquiry templates, science writing activities, and sentence frames. In addition, the post-implementation in using science inquiry in the class was 3.0—indicating that all teachers reported using science inquiry "all the time." These results suggest that a strong influence of the project was leading teachers to internalize core ScICAM practices.

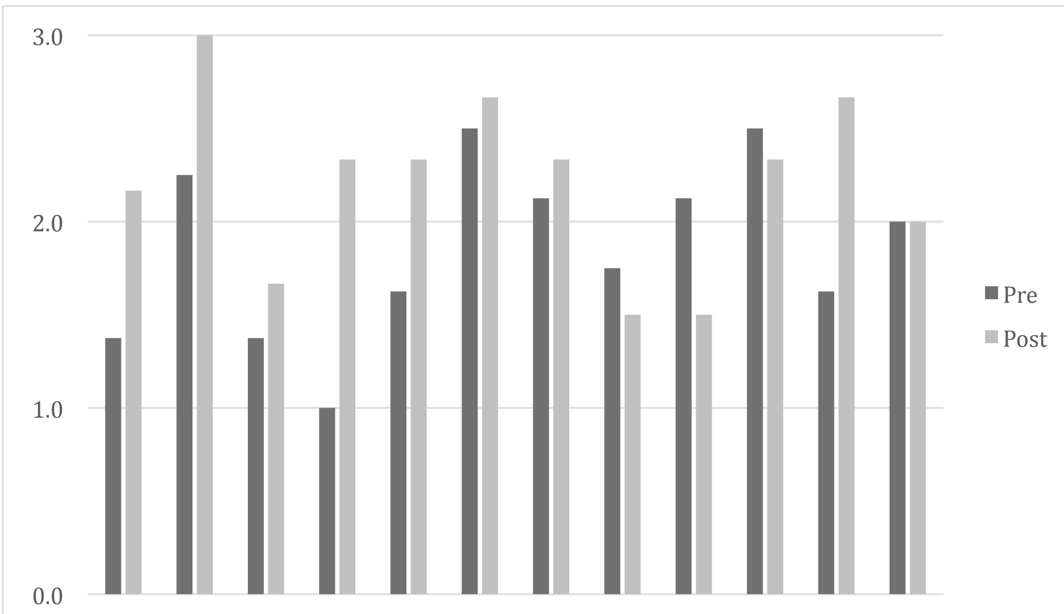

Figure 3. *Teacher self-reported frequency of use of the ScICAM active ingredients pre- and post-implementation.* N = *8*.

Classroom observational results (one per teacher) by three independent observers using the ScICAM Observational Protocol supported interpretations that teacher practices were reasonably well aligned with the ScICAM approach. Teachers' average observational scores ranged from 2.5 to 3.4; this equates to ratings judging the ScICAM pedagogical practices to fall between "emerging" and "understanding"—a promising finding, given the short implementation period of two months. (An example of a Grade 1 classroom vignette recreated from observational field notes is available at http://louisville.edu/education/centers/crmstd/scicam-vignette.docx)

Research Question 3

The promise of positive EL student outcomes was evaluated using paired sample *t*-tests on the student Work Sampling Checklist scores (see Table 2). The results indicated significant pre- to-post gains in three main outcomes: *literacy*, $t(30) = -7.69$, $p < .001$; *science*, $t(30) = -5.95$, $p < .001$; and *social behavior*, $t(28) = -5.40$, $p < .001$.

Consistent with previous research on early-implementation outcomes, the gains for literacy (Cohen's $d = 0.95$) were larger than those for science (Cohen's $d = 0.83$). These two effects are considered to be large according to Cohen's *d* interpretation guidelines (where an effect of 0.2 is considered *small*, an effect of 0.5 is considered *medium*, and an effect of 0.8 or greater is considered *large;* Cohen, 1988). Similarly, there were significant pre- to-post gains in *writing* (e.g., "Uses writing strategies to convey ideas"; "Writes for different purposes"), $t(30) = –5.70$, $p < .001$, and *building explanations* (e.g., "Uses data/evidence to construct reasonable explanations"; "Discusses and justifies merits of explanation"), $t(30) = –6.30$, $p < .001$. Notably, student ability to build explanations in science had a larger gain (Cohen's $d = 0.91$) than that for writing (Cohen's $d = 0.70$).

The effect for *social behavior* was medium to high ($d = 0.65$; see Table 2). Significantly, while the corresponding increase in the overall *social behavior* score was of about 23%, there were substantial differences in the program participation impact on different social behavior subskills, as measured by the Work Sampling Checklist subscales. That is, student gains were less pronounced for *interpersonal* (e.g., "Interacts easily with peers"; "Participates in the group life of the class") and *self-control* (e.g., "Manages transitions and adapts to new places and events"; "Follows classroom rules and routines") skills—about 17% and 15%, respectively. The increase was most pronounced for *approaches to learning* (e.g., "Shows eagerness and curiosity as a learner"; "Sustains attention to work over a period of time") and *self-concept* (e.g., "Demonstrates self-confidence"; "Shows initiative and self-direction") skills—about 38% and 31%, respectively.

Table 2 *Student Work Sampling Checklists: Descriptive Statistics, t-Test Results, and Effect Sizes*

	Pre-Test *M (SD)*	Post-Test *M (SD)*	*t(30)*	Cohen's *d*	Effect Size Interpretation[b]
Literacy	1.20 (0.53)	1.64 (0.39)	–7.69***	**0.95**	Large
Writing	1.20 (0.66)	1.60 (0.47)	–5.70***	**0.70**	Medium to Large
Science	1.25 (0.50)	1.62 (0.39)	–5.95***	**0.83**	Large
Building explanations	1.01 (0.69)	1.56 (0.50)	–6.30***	**0.91**	Large
Social Behavior	1.33 (0.49)	1.62 (0.39)	–5.40***[a]	**0.65**	Medium to Large

Notes: $N = 31$. ***p<.001. [a]28 degrees of freedom due to missing post-tests. [b]Cohen's *d* interpretation: small $d = 0.2$; medium $d = 0.5$; large $d = 0.8$ (Cohen, 1988).

Conclusion

Several trends support the importance of integrated science-literacy instruction for native English-speaking and English-learning students. The National Research Council "Framework for K–12 Science Education" (NRC, 2012) calls for greater emphasis on meaningful learning and the demonstration of deep understanding of scientific content by asking students to produce sophisticated communications about their learning. Content-Based Instruction for ELs (Grabe & Stoller, 1997; see also Janzen, 2008) and the Reading in the Content Areas (Saul, 2003) movements promote similar integration of literacy, language, and content learning. The recent publication of the Common Core State Standards (the Standards; CCSSI, 2010) has put forward new but related literacy expectations in content areas. While advocating for approaches to literacy instruction that are both integrated and interdisciplinary, the Standards' developers stop short of providing concrete instructional recommendations for how these goals should be reached, referring teachers to "whatever tools and knowledge their professional judgment and experience identify as most helpful" (p. 4). To inform practice, then, it becomes critical to investigate the effectiveness of existing instructional models to support simultaneous language, content, and social development across varied student populations.

This pilot study—conducted in a state that adopted both the Common Core and Next Generation Science Standards—addressed the above-mentioned need by providing preliminary evidence on the effectiveness of the ScICAM approach to support the science and literacy learning, as well as the social adjustment of, elementary ELs—the fastest growing student population in the U.S. schools. These results serve as a proof-of-concept that teachers working with ELs find the approach useful and are likely to display a high level of buy-in into the approach as well as the willingness to regularly implement ScICAM practices in their teaching. The student outcomes showed that ELs experiencing ScICAM-informed teaching practices may simultaneously show substantial growth in multiple domains, including science, language, and social learning. While the benefits of inquiry for supporting the development of both science content knowledge and second language skills have been long recognized (e.g., Amaral, Garrison, & Klentschy, 2002; Lee, Deaktor, Hart, Cuevas, & Enders, 2005; see also Lee, 2005), the results of this study also indicate that inquiry-based instruction can facilitate ELs' social adjustment in terms of improving their interpersonal skills, approaches to learning, self-control, and self-concept.

The positive impact of inquiry-based instruction on ELs' social adjustment may be attributed to several features of this approach. First, cooperative learning environments—where students work together with each other and with the teacher on developing research questions, engaging in active investigations, and presenting findings to compare with others through oral argumentation, writing, and other multimodal representation (Norton-Meier et al., 2008)—are a natural place for students to develop self-control and interpersonal skills and to internalize more effective approaches to learning. Second, the guided inquiry processes (see Table 1) allow for a gradual buildup of students' science and literacy expertise, thus contributing to improvement in their self-concepts; in particular, cooperative learning allows for extended practice with the language and content through multiple opportunities for meaning negotiation (e.g., argumentation, feedback, paraphrase) and provides additional contextual cues (e.g., hands-on, gestures, intonation) to facilitate student comprehension and production. Third, the high-interest science topics explored through investigations and multimodal literacy scaffolds (e.g., graphic organizers, consulting the experts) are likely to increase student curiosity and eagerness for learning (Grabe & Stoller, 1997).

In terms of future research, this pilot study provides adequate evidence to support larger, follow-up investigations of the cooperative learning approach. Teacher increase in the use of inquiry and writing scaffolds (see Figure 2) and student growth in the ability to express their understandings through oral and written modes (see Table 2) suggest that the ScICAM practices are effective in targeting some of the key practices identified by the Next Generation Science Standards (NGSS, 2013) as essential for all students to learn—namely, planning and carrying out investigations, constructing explanations, and communicating information. This is particularly important in the light of the federal No Child Left Behind emphasis on mathematics and language arts performance to measure student academic achievement and the corresponding de-emphasis on science and other subjects (to allow for more instructional time for the two tested subjects). The ScICAM model offers a well-designed approach to seamlessly integrate foundational language arts skills (language and literacy) with science, thus providing for instructional opportunities to synergistically bolster a spectrum of student skills and concept-building across the two subject areas.

In terms of practice, several recommendations emerge from this study. First, the results suggest that allowing more opportunities for students to engage in meaning negotiation (see Table 1) may benefit ELs academically and socially. The ScICAM approach emphasizes the need for students to live the language of science as they learn about science, moving beyond basic communication of ideas—relaying information—to increased opportunities for students to negotiate meaning, both publically and privately. Such constructive and collaborative work would allow students to experience features of scientific work (as experienced by scientists) as they are guided through a recursive cycle of posing questions, gathering data, and making claims based on evidence, while refining explanations through multiple negotiation opportunities (from exploration of pre-instructional understandings, to inquiry, to meaning construction, and to reflection; see Table 1). In the pedagogy of negotiation, the role of questioning is not simply to elicit answers, but to push students' thinking and participation in the community of scientific practice.

Second, the results of this study suggest that embedding negotiation, language, and literacy into science inquiry (i.e., using language and literacy as learning tools during guided science activities; see Table 1) and balancing between implicit (e.g., teacher questioning techniques, extended input and output during investigations and negotiations) and explicit (word-, sentence-, and discourse-level scaffolds) instruction may be most optimal in supporting ELs' development of language skills. Such embeddedness and negotiation opportunities may serve as critical means for integrating students' home discourses, and serving as starting points for their own construction of scientific understandings, which gradually will become aligned to scientifically accepted understandings through inquiry and argumentation.

Finally, to enable negotiation and embeddedness to occur in the classroom, teachers need to recognize that their students' rich histories and funds of knowledge are the basis for developing questions and new understandings, and thus are foundational for the negotiated, argument-based nature of the science learning. This necessitates a shift in pedagogy to support opportunities for collaborative interactions, allowing for learning with and from other students to support both academic and social development among ELs.

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